THE

NAUTICAL

STEAM ENGINE

EXPLAINED

AND

ITS POWERS AND CAPABILITIES DESCRIBED

FOR THE USE OF

OFFICERS OF THE NAVY

AND OTHERS INTERESTED IN THE IMPORTANT RESULTS OF

STEAM NAVIGATION

BY

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TO THE

OFFICERS

OF

THE ROYAL NAVY

THIS WORK

IS

RESPECTFULLY DEDICATED,

BY

THEIR HUMBLE SERVANT,

ROBERT ROBINSON,

COMMANDER, R.N.

LONDON,
APRIL 10, 1839.

PREFACE.

The desire of being useful, and of communicating to others the knowledge I have myself acquired, at the expense of much time and labour, have been my motives for undertaking this little work. I have dedicated it to the Officers of the Navy. It has no pretension to originality, it is a selection and compilation from what others have written before me, but my object has been to compress, in a small space, such a description of the properties of steam, and the nature of the Marine Engine,

as shall enable any officer, after having read this book, to understand the principles, names, and natures of the parts of any engine he may see, and to put him in the way of asking such questions as shall ensure his getting an answer intelligible and true.

It is hardly necessary to say a word on the importance of the subject to us all. Every officer must feel that a knowledge of the nature and properties of the steam engine, has become as essential as a knowledge of seamanship or gunnery.

It is evident, that whatever of dash, whatever of enterprize, whatever of combined prudence and skill, is to be performed in a future war, will be performed through the agency of Steam. The high road to distinction and fame will be found on the Paddle box of a Steamer, but to gain this fame, to achieve this

distinction, it is indispensable that officers should add, to a thorough knowledge of seamanship and gunnery, to nerve, to enterprize, to prudent daring, a knowledge of the steam engine, an acquaintance with the power which is to be their right arm, and their strong staff.

Formerly there was a vague idea in people's minds that a good seaman, placed behind a thirty-two pounder, without any knowledge of the weapon he was to wield, would prove an efficient and accomplished marksman; we received some practical lessons, at the close of the war, on this head; the work of Sir Howard Douglas, the establishment of the Excellent, and the orders of the Admiralty, have brought it practically home to all men's minds, that a thorough knowledge of a weapon is essential to the perfect use thereof.

I think this position, which I conceive every body will be willing to allow, as regards naval gunnery, holds equally true with regard to steam.

It is a most powerful weapon; to use it in perfection its nature must be thoroughly known.

I have experienced, and I have heard others complain of, the difficulty there is in procuring information on this head; we go into engine rooms, we look at the outside of an engine; various rods of highly polished iron are moving about, a beam is observed vibrating up and down, all is clean, bright, and well arranged; but the working parts of the engine, the moving power is entirely shut up from our sight, and after staying a few minutes, and perhaps asking a question or two, which from the very depth of ignorance it betrays, it is

scarce possible the engineer either can or will answer, we walk up again, with no addition to our knowledge, and rather convinced that the whole subject is incomprehensible.

If we turn to books, we find descriptions of land engines, and of old methods of working steam in abundance; we are told of what Hero, of Alexandria did, A. D., 420; what the Marquis of Worcester thought about; of Newcomen, and other great men of their day, to whom science is much indebted, but little that can enable us to understand what we see on board a steam vessel, or to call the different parts of the engine by their right names. To those who have leisure, all these works are highly interesting, and they should be read by all who can afford to purchase them; my object is to smooth the way to those who have neither leisure to read, nor money to purchase,

the various expensive and voluminous publications which treat on the matter of steam.

In the introductory chapter, I have borrowed largely from a little work by Hugo Reed, full of valuable information, and which only wants a practical description of the different parts of the Marine Engine to be a perfect manual to the beginner.

I have also made great use of Tredgold's work, the price and size of which render it a sealed book to the majority of Naval Officers.

If any one, after reading this work, shall desire to know more, and shall feel that he can now shape his enquiries judiciously, and consequently acquire knowledge from the reply; if any one is tempted to take up Tredgold, or to visit an engine, with a feeling that a first step has been assisted by this book, I shall feel

much gratified, and shall have attained the object for which I wrote it.

Before I conclude, I desire to return my best and most cordial thanks to Mr. R. Napier, of Glasgow, for the kind and liberal treatment extended to me while I was in that city, and for the means he placed at my disposal of seeing thoroughly all his works, and of acquiring knowledge on this interesting subject.

THE

NAUTICAL STEAM ENGINE.

PART I.

PRELIMINARY MATTER.

STEAM is the vapour of boiling water.

A Steam Engine is therefore a machine, the moving power of which is the vapour of boiling water.

A Steam Engine has, therefore, two great divisions:

The first, the properties belonging to the nature of the prime mover, whereby a moving power is procured.

The second, the engine, by which those powers are made effective for the general production of motion.

We shall begin with a general view of the first division of this subject, namely, the pro-

perties belonging to the nature of the prime mover, and then proceed to describe the engine, by which those powers are made effective for the general production of motion. We shall, however, in this latter part, confine ourselves to the simple description of the Marine Steam Engine.

FIRST DIVISION.

The properties belonging to the nature of the prime mover, or steam, whereby a moving power is procured.

The sources of moving power are three:—

1st. Animal strength.

2nd. Attraction.

3rd. Repulsion.

The first need only be referred to, as it is used to compare the power of steam engines with the animal force of horses.

2nd. The moving power of attraction exists in all bodies, and is used in what are called atmospheric engines. Attraction gives a moving power in two ways; first, by the descent of heavy bodies; secondly, by the pressure of the atmosphere.

This is a most important element in causing motion; its existence and force are proved as follows:

Take a glass tube of about 33 inches long, whose orifice shall be equal to a square inch, and let it be closed at one end; fill this tube with quicksilver, and stop the open end with a cork, or the finger, invert this tube into a vessel of mercury, withdraw the stopper from the open end, taking care that the orifice of the tube shall be below the surface of the mercury in the vessel, and the mercury in the tube will descend to about the height of 30 inches, and there stop. Now, by the laws of gravity, this column of mercury ought to fall, and would fall into the vessel of mercury with which it communicates, if not restrained by some other force. That force is the pressure of the atmosphere on the surface of the mercury in the vessel, and is sufficient to hold it in balance. Now the weight of a column of a square inch of mercury, 30 inches long, is about $14\frac{3}{4}$lbs., and we find the pressure of the atmosphere just balances this weight. We therefore call the pressure of the atmosphere 14·75lbs. on every square inch at the surface of the earth.

The tube above described is the common barometer. The space left in this tube above the mercury contains nothing—is a vacuum.

A column of a square inch of water, 33·87 feet long, is also balanced by the pressure of the atmosphere.

The pressure of the atmosphere at the earth's surface is equal in all directions, and is the whole weight of the atmosphere, from the earth's surface to the limit of atmospheric air, supposed to be forty-five miles high.

Hence it is easily seen, that the higher we are from the earth's surface, the less will be the atmospheric pressure.

Therefore, on the tops of high mountains, the pressure of the atmosphere will be diminished by the amount of the superincumbent air taken off by the height obtained.

Hence the use of the barometer in measuring elevations.

Every space on the surface of the earth being filled with air, or a balance to its pressure, it can exert no force as a moving power, till we have procured an open space or vacuum into which the air will rush with great force.

If a tube containing no air or other body be inverted into a vessel of mercury, the pressure

of the air will force quicksilver into the tube to the height of about 30 inches.

Thus the pressure of the atmosphere is in itself a moving power, and exerts a force equal to 14·75lbs. on every square inch, provided it be not resisted by air, or, in other words, if it be exerted in vacuo.

We are then led to consider how this resistance may be withdrawn, or a vacuum procured.

This can be done by admitting the vapour of boiling water into a cylinder in which a piston moves; but the vapour of water would offer equal or superior resistance to the air, which it would easily expel; but if we suddenly cool or condense this vapour, a kind of vacuum is formed, and the pressure of the atmosphere will then act upon the piston as a moving power. This is the principle of Newcomen's engine, improperly called a steam engine, for its moving power is not steam.

3rd. Repulsion, as a moving power, exists in all bodies, and is largely developed by heat.

The laws of heat must be considered.

The particles of heat are highly repulsive of each other, but have great attraction for the particles of all other bodies.

Heat passes among bodies in two ways:

1st. By radiation.

2nd. By conduction.

1st. By radiation, we mean that the particles of heat are thrown out in all directions in straight lines, like radii from a circle.

Smooth, highly polished surfaces radiate heat slower than rough porous substances; they retain heat longest, cool slowest, absorb least, and reflect most.

Dark, rough, porous substances radiate heat fast, absorb much, reflect little, and cool quickly.

Hence the cylinder of a steam engine should be highly polished, that it may radiate heat slowly.

Conduction is the passage of heat along bodies from particle to particle, and from substance to substance, when in connexion.

It is more or less rapid in different substances, and appears to be nearly in proportion to the densities of the different bodies.

Liquids conduct very slowly if heat be applied to the upper part of the fluid; but very rapidly if the heat be applied to their lower parts.

Heat expands all bodies.

Air is expanded by its particles being separated and made lighter by heat; hence the use of heat as a means of ventilation.

Heat is the cause of the elastic power which ærial bodies possess.

Heat expands liquids into vapour, attended by a change of form.

Heat, in expanding bodies, exercises the least effect on solids, more on liquids, and most on gases. All gases undergo the same expansion from the same increase of temperature.

The elastic force of gas is exactly equal to the force by which it is confined.

When a given quantity of gas is diminished in bulk, or confined in a smaller space, its density is increased.

The elastic force of any gas is in direct proportion to its density, and in inverse proportion to its bulk.

Any increase in the temperature of a gas increases its elastic force; and any decrease of temperature effects a corresponding decrease of elastic force.

All gases contain within themselves a source of expansion, which is only prevented from

operating by some other force which compresses the gas; this is shewn by the expansion of the air in a flaccid bladder placed in an exhausted receiver.

Solids have not this power, nor have liquids. Liquids are almost incompressible.

The elastic force of gas is different from its weight; 10 grains of air would totally prevent the entrance of mercury into the barometer tube above described, although the weight of the air exerts a pressure of 14·75lbs. on the square inch; any quantity of air, however minute, admitted into the empty part of the barometer tube, will depress the mercury.

An important use of this fact can be made in measuring the strength of any gas, by making a communication between the gas desired to be measured and the empty part of the barometer tube, when the mercury will be depressed in the tube, or driven out altogether, according to the strength of the gas.

In this way a gauge can be applied to the boiler, to test the strength of steam in it, and also to the condenser, to ascertain the degree of the vacuum in it, or the strength of the uncondensed vapour that may remain in it.

Confined gas may be used in two ways, to procure motion, first, as in the instance of the flaccid bladder, or more clearly, by supposing a piston in a cylinder, and that the cylinder above and below the piston is filled with gas of the same density, then, by withdrawing the gas on one side, the gas on the other side expands, and moves the piston.

Secondly, by increasing the temperature of the gas.

The elastic nature of air enables us to withdraw air from a vessel, by means of an air pump.

The air pump forms an important feature in the common Steam Engine.

Let us conceive a piston working in a cylinder, fitting air-tight to the neck of a vessel, to be exhausted of its air.

At the neck of this vessel, suppose a valve on an hinge, opening upwards only; and a similar valve in the piston, on forcing down the piston the compressed air in the cylinder will force open the hinge valve of the piston and escape, the space below the piston will then contain nothing; on raising the piston, the pressure of the atmosphere will close the

valve in it, and the air in the air vessel, being no longer pressed down by the portion of air above it, which has been removed by the piston, will force up the valve in its neck, expand, and occupy the whole space in the cylinder below the piston; on pressing down the piston again, the pressure shuts the valve in the neck of the air vessel, and opens the valve in the piston; all the air between the neck of the air vessel and the top of the cylinder is again driven out, and on raising the piston, is replaced from the air vessel, by the expansive power of air; at each repetition this expansive force is diminished, and more and more air withdrawn, till the vessel is nearly emptied, though it is hardly possible entirely to do so.

When heat causes a liquid to boil, enormous expansion takes place. Vapour is produced colourless and invisible.

Vapour of water is expanded 1711 times, or a cubic inch of water will produce a cubic foot of steam nearly.*

Vapour rises from most liquids at tempera-

* Gases must be heated to 48° of Fahrenheit to double their bulk.

tures below the boiling point, but in such cases from the surface only.

Pressure retards vapourization.

The common pressure on the surface of the earth, indicated by the barometer, standing at 30 in. is $14\frac{3}{4}$ pounds on a square inch; at this pressure, water boils at 212° of Fahrenheit.

That is, pure fresh water will boil at 212° of Fahrenheit, but salt water will require more heat, varying according to the degree of the saltness of the water.

The temperature required to boil salt water will be a good test of the degree of its saltness.

Thus sea water containing $\frac{1}{33}$ of its weight of salt, will boil at 213° under the ordinary atmospheric pressure, but when saturated with salt, or containing $\frac{11}{33}$ of its weight of salt, it will not boil under 226° of Fahrenheit.

But at considerable elevations, the pressure of the atmosphere being less, by the amount of the weight of the column of air subtracted, water will boil at temperatures lower than 212°, and in fact, in a vacuum at a temperature below 100°.

By increasing the amount of pressure on the surface of the water, we increase the elastic

force of the steam, as also its temperature. The elastic force of the steam will therefore always be equal to the pressure under which it is raised, and this has no limit, but the strength of the vessel containing it.

As already stated, if the pressure of the atmosphere be indicated by the barometer standing at 30°, water will boil at 212° of Fahrenheit in an open vessel, and the steam will have the same elastic force, or press on the surface of any body with a force equal to 14·75lbs. on the square inch.

Vapour rises from water at all temperatures, but of diminished density and elastic force, both of which increase with the temperature. The above law of vapour relates to vapour in contact with the water of its generation: when vapour is cut off from the water of its generation, increase of temperature increases its elastic force, without increasing its density.

Latent heat, is heat which eludes the thermometer, and which we find to exist, in contradistinction to free or sensible heat, which is indicated by a thermometer. It is one of the most curious and important phenomena attending vapourization.

When heat is applied to a vessel containing water, exposed to the mean atmospheric pressure on the earth's surface, the temperature of the water increases till it has reached 212° of Fahrenheit, after which any addition of heat causes no corresponding rise in the temperature of the water; but steam will be formed continually, till the whole water is evaporated, and this steam will have the temperature of the water by which it was generated, viz. 212°. Now, it appears that up to the temperature of 212°, the continued application of heat causes a continued accession of temperature to the water, but that after the water has reached that point, the continued application of heat has no longer the same effect in raising the temperature.

And we are led to enquire what becomes of the additional heat. It will be found to have entered the steam in a latent or concealed state, and it may be recovered from the steam as follows.

Suppose the steam to have been collected as it was formed, and to have been kept at the temperature of 212°, now if we have two vessels containing equal weights of water, at the temperature of 60°, and if we introduced equal

weights of water at 212° and of steam at 212° into these vessels, it will be found that the temperature of the water into which steam has been introduced, is far higher than that of the vessel into which water has been introduced. We conclude that the steam possesses heat in a latent state not indicated by the thermometer, and that it can give out this heat into a free or sensible state.

It will also be found that if it requires a certain application of heat to raise water, in temperature from 32° to 212° or through 180° of temperature, it will require $5\frac{5}{9}$ times that application of heat to convert the water into vapour, therefore if 180° is the measure of the heat required to bring water from 32° to the boiling point, $5\frac{5}{9}$ times that measure, ($180 \times 5\frac{5}{9}$) or 1000° will be the measure of the heat required to turn that water wholly into vapour.

The additional 1000° of heat acquired by steam, in its conversion from water to vapour, is called the latent heat of steam.

And again, with reference to the first experiment of the two vessels containing equal weights of water at 60°, let a sufficient weight of water at 212° be introduced into one, to raise

the temperature 1°, if we introduce the same weight of steam, at 212° into the other, the temperature will be increased $5\frac{5}{9}$°; this additional heat has been recovered from the steam into which it had entered in a latent state, and has been given out into a free and sensible state, indicated by the thermometer.

The same takes place during the melting of solids and during their congelation.

In melting they absorb heat which does not raise their temperature; in congealing, they give out this heat into the free or sensible state.

Thus let a mass of ice, at the temperature of 32°, be exposed to any degree of heat, the temperature of the ice will remain at 32° till the whole of it is melted; and it is found that it requires 140 times as much heat wholly to liquify the ice as is required to raise the temperature of water at 32° one degree; that is, to liquify a given weight of ice, requires as much heat as will suffice to raise the same weight of water from 32° to 172° or 140° of Fahrenheit.

The latent heat of water is therefore called 140°.

These important laws of heat may thus be summed up: when solids become liquids, and when liquids become gaseous, they absorb a quantity of caloric, which does not raise their temperature.

They evolve this caloric into the free or sensible state when they return to their former state.

It appears, when water boils under a pressure less than that indicated by the barometer at 30 in., the same quantity of heat is still required to vapourize the same quantity of water; for though the temperature of the water will be less in proportion to the diminished amount of pressure, the sum of the sensible and latent heat will be the same as before, the latent heat being, in all cases, as much more as the sensible heat is less, and the heat required to convert water wholly into steam, will always be the sum of these two; or the heat required to convert water at 32° wholly into vapour, will always be 1180°, under whatever pressure the water may be boiled; thus, when 212° is the boiling point of water, the sensible heat, reckoning from the freezing to the boiling point, is 180°, and this

added to 1000°, (the latent heat,) is 1180°. But if 160° were the boiling point of water, the sensible heat being only (reckoning, as before, from the freezing to the boiling point,) 128°, the latent heat would be 1052: the sum of the two being 1180°, the heat required for the conversion of water into steam. Therefore there would be no economy in raising steam at low temperatures or under low pressures, as was once supposed.

When water is contained in a closed vessel, we can, by putting weights on its cover, retard the temperature at which its vapourization begins, and, by so doing, greatly increase the elastic force of the vapour, as well as its temperature.

As we before observed, the elastic force of steam will always be equal to the pressure under which it was raised; thus, if we load the cover of the vessel with a weight of 14¾lbs. on each square inch of its surface, the steam generated in this vessel will have an elastic force of 14¾lbs. over and above the atmospheric pressure, which is also = to 14¾lbs. on the square inch, and is generally called steam of two atmospheres, having twice the atmo-

spheric pressure. If a thermometer be inserted air-tight into the cover of this vessel, the temperature of the water will be found to be 250°; but the latent heat of the steam will be as many degrees less than 1000° as the sensible heat is more than 212°; thus, from 32° to 250° is 218°, the sensible heat, which is 38° more than 180°; the latent heat will therefore be less than 1000 by the same amount, or 1000—38° = 962°, and the sum of the free or sensible heat 218°, and the latent 962°, is the constant quantity 1180°.

Now it has been ascertained by experiment, that the measure of latent heat which can be recovered from steam at 212° is 1000°; at 250°, 962°; at 160°, 1052°. We therefore come to the conclusion, that the heat required for the conversion of water into steam is a constant quantity, and that the sum of the sensible and latent heat is always the same under all pressures, the latter being as much less as the former is more.

From this we deduce the important fact, that the same quantity of heat is required to convert a given quantity of water into vapour under whatever pressure the water may be

boiled; that is, that the same quantity of fuel will suffice to convert a given quantity of water into steam, whether the force of the steam be equal to one, two, three, or ten atmospheres.

But when it is said that the same quantity of heat will convert a cubic foot of water into steam equal in elastic force to the pressure of one, two, or ten atmospheres, it is to be remembered, that in proportion as the elastic force is augmented, the density increases, or the volume diminishes; that is to say, that if the space occupied by a cubic foot of water converted into steam of the atmospheric pressure be called 1, the volume occupied by steam from a cubic foot of water raised under a pressure of two atmospheres will be ½, and so on, the elastic force being in proportion to the density, and the volume in inverse proportion to the elastic force.

If the elastic force of steam from a cubic foot of water raised under the pressure of one atmosphere be called 1, the elastic force of steam from the same quantity of water raised under a pressure of two atmospheres would be 2, and under a pressure of ten atmospheres 10.

Let the mechanical force or effect of steam

be represented by its quantity or volume, multiplied by its elastic force, then in the case of steam from a cubic foot of water raised under the pressure of one atmosphere,

the quantity or volume of steam 1 \
the elastic force . . . 1 } $1 \times 1 = 1$,

= the mechanical force or effect of a cubic foot of water vapourized under the above pressure.

And in the case of steam from a cubic foot of water raised under a pressure of two atmospheres,

the quantity or volume of steam $\frac{1}{2}$, \
multiplied by the elastic force 2, } $\frac{1}{2} \times 2 = 1$,

the mechanical effect of a cubic foot of water vapourized as above.

Again, in the case of steam from a cubic foot of water raised under the pressure of ten atmospheres,

the volume or quantity of vapour $\frac{1}{10}$, \
the elastic force . . . 10, } $\frac{1}{10} \times 10$

= 1, the mechanical effect or force from a cubic foot of water vapourized at a pressure of ten atmospheres.

Thus we see the mechanical effect or power acquired from a cubic foot of water converted into steam is the same under whatever pres-

sure the steam may be raised; so that if we wish to double our mechanical power, we must convert two cubic feet of water into steam; and any increase of mechanical effect is to be acquired only by evaporating additional quantities of water.

Now, as equal quantities of heat evaporate equal quantities of water, the mechanical effect or power must be in direct proportion to the amount of heat applied, or to the consumption of fuel.

It is clear thence, that supposing heat to be equally well applied, and steam used in the same way, there can be no economy in the use of high pressure steam. It is also clear, that the more steam is consumed, the more water must be evaporated, and the more fuel used; hence any economy of steam, any smaller consumption of steam, will lessen the consumption of fuel. Now we have before stated, that equal quantities of fuel evaporate equal quantities of water, under every pressure, high or low, and form equal weights of steam, but not equal volumes; and we said that the volume of steam was in inverse proportion to its density and elastic force. It is customary to con-

sider it so; but there is a slight difference in the volume of steam at higher pressures, by which a slight increase in the mechanical effect may be obtained.

Thus the volume of steam from a cubic foot of water, evaporated under a pressure of 30 in. of mercury, is 1711 feet. The volume of steam from the same quantity of water evaporated under a pressure of 60 in. of mercury, is 904; and the volume of steam from the same quantity evaporated under a pressure of 120 in. of mercury, is 481 feet.

In the first case, then, the mechanical effect will be the volume multiplied by the elastic force, that is, $1711 \times 1 = 1711$.

In the second, the volume 904 multiplied by the elastic force $2 = 1808$.

In the third, the volume 481 multiplied by the elastic force $4 = 1924$.

There is also considerable economy of steam by using its expansive power; as by introducing a certain quantity of steam into a cylinder, and then shutting off the further supply of steam, and allowing that already in the cylinder to expand, and finish the remainder of the stroke.

The following table will shew how much is saved by this method of working steam.

If the steam be stopped at

$\frac{1}{2}$	the effect of the quantity admitted is multiplied by	1·69
$\frac{1}{3}$		2·10
$\frac{1}{4}$		2·39
$\frac{1}{8}$		3·08

Thus let the whole of the steam admitted during the whole stroke be called 2. If the steam admitted be shut off at half the stroke, the quantity admitted, $1 \times 1{\cdot}69 = 1{\cdot}69$ the effect produced.

Again, let 6 be the effect of steam admitted during the whole stroke, and let the steam be cut off at one-third, then 2 is the quantity admitted, and that multiplied by 2·1, gives 4·2 as the effect produced; thus, while we save a quantity of steam represented by 4, we only lose a quantity of effect represented by 1·8.

Another important law of the expansion of steam, we deduce from observing that its elastic force is exactly equal to the force by which it is confined.

If, therefore, we raise steam under a pressure of one, two, or ten atmospheres, the steam will expand to once, twice, or ten times its

bulk, and still retain an elasticity equal to the pressure of the atmosphere; thus steam raised under a pressure of two atmospheres would rush into the air with the same velocity that air rushes into a vacuum.

We have now detailed some of the most remarkable properties attending the vapourization of water; and it now remains for us to consider in a few words the condensation of vapour, or the return of vapour to the liquid state.

Any given space can contain a certain quantity only of vapour at a given temperature: its quantity is in proportion to its temperature. Hence, if a quantity of vapour in a confined space be reduced in temperature, the space having contained as much vapour as it could at a previous temperature, a certain quantity of vapour will return to a liquid state, and the remainder will expand, and fill the whole space, diminished in density and elastic force. A perfect vacuum cannot be obtained by condensation from cold water.

Condensation of vapour is effected by a reduction of its temperature, and no mechanical

pressure can effect this without the reduction of temperature.

When a cubic foot of water is converted into steam at 212°, it occupies a space of 1711 feet; but on condensation in a close vessel, the 1711 feet return to one foot of water, leaving 1710 feet with nothing in them, or a vacuum.

We have already seen in a perfect vacuum a moving power of nearly 15lbs. on the square inch is obtained from the pressure of the atmosphere, and the more perfect the vacuum, the greater the power.

It is a chief object, in all steam engines, to obtain this vacuum as perfect as possible.

The ordinary way of condensing steam is by the admission of a quantity of cold water into the vessel containing the steam sufficient to reduce its temperature to 100° of Fahrenheit, which will still leave some vapour in the vessel uncondensed; but the elastic force, which will only be equal to 2 in. of mercury, a vacuum of this kind will give a moving power of little less than 14lbs. on the square inch.

We have now come to the fundamental principle of a steam engine, which consists in establishing as perfect a vacuum as can be procured

on one side of a piston moving air-tight in a cylinder, and pressing on the other side with a certain force of steam; a moving power of almost infinite strength is thus procured, and by alternately forming the vacuum above and below the piston, and admitting the pressure of steam on the opposite sides of the piston, an alternate up-and-down motion is procured, which, by means of machinery, can be rendered into a continued circular one, if desired.

This is the principle on which all low pressure or condensing engines are constructed, and the difference between the mediums on each side of the piston constitutes the moving force of the engine: thus, let a piston have a surface of one square foot, or 144 square inches, let the pressure of steam above the force of the atmosphere be 2lb. on each square inch, and let the vacuum below the piston be indicated by 26 in. of mercury or 13lbs. nearly, then the piston will be pressed by a force on each square inch of 14·7, + 2 = 16·7lbs. nearly, and resisted by a force on each square inch, indicated by 1·7lb. nearly, or 15lbs. on each square inch: the difference between these two mediums represents the moving power on the

piston's surface. In a high pressure or non-condensing engine, the moving power is still the difference between the mediums on the opposite sides of the piston; for instance, if steam of four atmospheres is to be employed, the upper side of the piston will be pressed by that force, but the lower not having a vacuum formed beneath it, is resisted by the pressure of the atmosphere, and the difference between one atmosphere and four, or three is the moving power.

In a non-condensing engine, instead of a vacuum being formed alternately above and below the piston, a communication is formed with the atmosphere into which the steam escapes, at the end of its stroke, this communication is alternate like the condensation in the low pressure.

High pressure engines being worked by steam of much greater density than low pressure engines, do not offer the same advantages in condensation, and less is lost by neglecting to do so; they take up much less space, but require urgent fires and great strength of parts, and any accident that occurs to them, is proporionally much more destructive than to low pressure engines.

They also offer great advantages in using the steam expansively as before described, and if the expansion be considerable, the same ease will attend the condensation of high pressure steam, and the same advantages will flow from it, as follows the condensation of low pressure steam; for instance, if a cylinder full of steam is to be condensed, and that steam has the density of the atmosphere represented by 1, it will be condensed by admitting a quantity of water sufficient to reduce the temperature to 100°, and will then occupy 1700 times less space than before. But if the same cylinder full of steam is to be condensed, and that steam has a density of four atmospheres represented by 4, it will have been formed by four times the quantity of heat, from four times the quantity of water, and it must give up that heat before the steam can be reconverted into water; in short, four times the quantity of cold water required in the first instance, will be necessary in this.

As the condensation goes on in a vessel seperate from the cylinder, though communicating with it, and as after each emptying of the cylinder into the condenser, the cold water necessary for condensation and the condensed steam have to be removed, it is easily seen how

inconvenient condensing the steam would be, under such circumstances. But if a certain quantity of steam at four atmospheres be introduced into the cylinder, and cut off when it has driven the piston one fourth of its stroke, and if the cylinder be just so long as to allow the steam to expand to four times its bulk, the steam at the end of the stroke will then be only of atmospheric density, and be condensed as easily and with as much advantage, as in the first case. It is on this application of steam, that the most beneficial mechanical effect has been procured from it. It is only necessary here to state, that the water for condensation and the condensed steam are removed at each stroke, by a pump worked by the engine itself.

The above is an outline of the principle of the double acting engine invented by Watt, and is the fundamental principle both of marine and land engines, whether stationary or locomotive.

We have thus cursorily glanced over the properties belonging to the nature of the prime mover steam, and given a general idea how those properties are to be applied to the pro-

duction of motion. We chiefly notice the great expansion of vapour of water; the law by which its elastic force is in proportion to its density, its powers and law of expansion and condensation, and the fact that its mechanical effect will be in proportion to the quantity of water vapourized, we observe that its moving power is gained by the difference of the medium on each side of the piston, whether the engines be high or low pressure, or condensing and non-condensing.

And we conclude, that for general purposes, the most efficient, lasting, and economical engines, are those that combine the direct action of steam, with expansion and condensation.

PART II.

We are now to describe the engine by which the properties of steam are made available for the general production of motion; but we shall confine ourselves to that sort of engine used to propel vessels through the water, and proceed to give a general description of all the parts of a Marine Steam Engine.

The principal parts of the steam engine are:
- 1st, the cylinder;
- 2nd, the sliding valve;
- 3rd, the condenser;
- 4th, the air pump.

The working parts of the engine, viz.
- The sway beams or side levers;
- The side rods;
- Fork-head or cross-tail;

Connecting rod;
Intermediate shaft;
Paddle shafts and paddles;
Cranks, crank pins;
Eccentrics, and their gear;
The various pipes and pumps;
and, lastly, the source of all power and motion,
The boiler, and what belongs to it.

THE CYLINDER.

The cylinder is a cast-iron vessel, in which the piston is to move up and down, air and steam-tight.

After the cylinder is cast, it is bored with great care and exactness to the diameter required; this is a delicate operation, as much depends on the boring being truly cylindrical and central throughout the whole length of the cylinder. The bottom of the cylinder is generally cast in one piece with the cylinder itself, leaving a hole in it sufficiently large to admit the boring rod to pass through it; this hole is afterwards filled up by a circular plate of iron countersunk into the bottom of the cylinder, rusted in, and secured by bolts passed through and through, and rivetted on each side.

On one side of the cylinder, and cast with it, are two square projections called nosles, which enclose within them the steam ports, or apertures in the upper and lower part of the cylinder for the admission of steam; the ports open into the cylinder as high up and as low down as possible; opposite the lower steam port is a smaller aperture for an escape valve, the object

of which is to allow of the escape of any water that may be in the cylinder, the consequences of which will be explained further on.

A projecting flange is also cast on the upper and lower parts of the cylinder, and goes round it: the upper one to receive the bolts which screw down the cylinder cover, the lower one for the bolts which secure the cylinder to the foundation plate; this lower flange forms a square enclosing the cylinder, of equal breadth with the foundation plate.

The bottom of the cylinder is slightly concave, as is the upper part of the foundation plate intended for its reception; the piston being convex, is thus allowed to come close to the bottom of the cylinder; the plate which fills the hole of the boring rod is also concave, as the head of the piston rod projects a little through the piston.

In order to allow the steam to enter the cylinder as low down as possible, the bottom of the cylinder slopes away towards the lower port, and there is a corresponding projection on the outside.

The nosles of the cylinder have each a projecting flange, from the top to the bottom, for

the bolts which secure the slide case to them. Abreast of the ports the face of the nosle is flat, and edged with brass ground smooth; on these brass surfaces the faces of the slide are to travel.

The cylinder is closed at its upper end by a cover of cast-iron, which is ground exactly to the size of the cylinder, into which it enters; it has a projecting flange similar to the one on the top of the cylinder. Bolts, having a square head on one end and a screw cut on the other, pass through the flanges, secure the cover down steam-tight by means of nuts on their upper end, besides which, a gasket (plaited hemp), soaked in white-lead, is laid between the flanges, and effectually keeps the joint air and steam-tight.*

In the centre of the cylinder cover is a hole for the piston rod to play through; this hole is surrounded by a raised projection from the surface of the cover, called a stuffing box, a flange is cast with the stuffing box for the

* The cylinder cover is concave below, and abreast of the upper steam port it is cut away, that the steam may get in as high as possible, a groove is also cut out of the cover for the heads of the bolts in the piston.

bolts to pass through it which secure its cover, and in the inside of the stuffing box a small projecting ring, called a check, is cast, on which rests a brass ring, ground exactly to the size of the piston rod, which passes through it steam-tight; a little play is sometimes given between the edges of the brass ring and the inside of the stuffing box, in order to make allowance for any trifling irregularity in the boring of the cylinder. Above the brass ring is a hempen packing which surrounds the piston rod, and is forced in and confined to its place by the stuffing box cover.

The stuffing box cover is either of brass or cast-iron lined with brass. It fits exactly into the stuffing box in the cylinder cover. It has a flange corresponding to the one on the stuffing box; the lower part of the stuffing box cover presses against the hemp packing, and is screwed down very tight by nuts working on the ends of the bolts; the hole in it, through which the piston rod works, is ground accurately to the size of the rod, and its upper surface forms a grease cup, where melted tallow, or oil, is kept constantly lubricating the piston.

In the cylinder cover there is generally an escape valve, for the purpose of getting rid of any water that may be above the piston in the cylinder; it is a flat valve of brass, working on a spindle, the head of which rests against a lever; one end of the lever is loaded with a weight exceeding the pressure of the steam in the cylinder per square inch, and the other works on a hinge joint in the stuffing box. A small hole is also made in the cylinder for a grease cock, and for the purpose of using the indicator when desired

In some engines the steam pipe terminates in a flat cast-iron casing, which surrounds the cylinder between the nosles, and opens into the slide case from between them.

In this space also, in most of the engines made by Mr. R. Napier, a slide is fitted working in grooves, and moved by a rod working steam-tight through a stuffing box, &c., which cuts off the steam at a fixed portion of the stroke, allowing the expansive power of the remainder to complete the stroke.

In the cylinder works the piston; there are many kinds, but, generally, the old plan of a

hemp-packed piston is abandoned, and a metallic packing used instead; this kind improves by wear, and keeps steam-tight with far less friction than the hemp-packed piston.

The metallic piston is in several pieces—is made of cast-iron.

The main piece, or boss, of the piston is a circular piece of cast-iron, convex on its lower side; a conical hole passes through it to receive the end of the piston rod, which is secured to the piston by a cutter or wedge of iron passing through both.

The upper part of the piston is also convex, and forms a circle round the piston rod, considerably smaller than the diameter of the piston.

Between the upper and lower sides of the piston it is hollow, for the sake of lightness, leaving, however, a substantial thickness of metal round the piston rod, called the eye of the piston.

From the lower side of the piston, and at the distance of more or less than two inches (according to the size of the piston) from its outer diameter, a thick ring of metal, reaching nearly to the upper part of the piston, runs round it, containing several grooves; in each

of these grooves a steel spring is placed; this ring is cast in one with the main piece of the piston, surrounds the space left hollow in the centre of the piston, leaving between itself and the outer diameter of the piston a ledge, on which are placed the packing rings. The packing rings are rings of cast-iron, which are ground upon one another, and on the ledge on the lower side of the piston, till they fit so accurately upon one another as to be steam-tight; they are cut into two or more segments, the lower ring is fixed on the piston by small tenons, corresponding to circular holes in the piston; the segments are connected to each other in a similar way. From the back of each packing ring, a mortice of little depth is cut out opposite the grooves for the spring, and a small piece of cast-iron, flat on one side and half-round on the other, called a cod, is introduced, with its back bearing against the spring, and its flat face against the packing ring; it is thus continually pressed out against the sides of the cylinder, and so kept constantly steam-tight. Above this lower ring is a second one, similar to the other in all respects; the joints of the segments are on oppo-

site sides of the piston, and the cod which presses against the joints differs a little in shape from the others, being angular on the face that bears against the packing ring.

On the top of the packing rings comes the junk ring, which occupies the whole space from the boss of the piston to the sides; it also is ground steam-tight upon the packing rings, and on a ledge left on the top of the piston for its reception. The junk ring is bolted through the solid part of the piston between the springs, and thus completes the piston, which then presents both its surfaces convex.

Round the conical end of the piston rod are two small grooves, which are filled with packing, making the piston perfectly tight. Between the eye of the piston and the ring in which are the grooves or recesses for the springs, there are six or eight radii, or arms, of the same thickness of metal as the ring itself, these add to the strength of the piston, and between two of these arms, opposite to where the cutter passes through, an additional strengthening piece is introduced, which bears against the cutter. Each of the packing rings is pressed outwards by six or more springs,

placed in the recesses above described, each ring by its own springs; as, if there are twelve recesses, each ring has six springs bearing against it, and having no cod in the way of the springs that belong to the other ring, is not touched by them.

As the main piece of the piston is always ground to something less than the size of the cylinder, the elasticity of the springs allows for the unequal expansion of the piston and cylinder, and insures the packing rings always bearing against it, however long it may be in use.

PLATE I.

Fig. 1 represents a section of a cylinder; and fig. 2 a front view of the nosles; the letters on one correspond to those of the other.

a a a a, are the flanges that go round the cylinder; the upper one for the bolts of the cylinder cover, the lower for the bolts which secure the cylinder to its foundation plate.

b b b b b b, are the two steam ports, passing through the thickness of metal of the cylinder, and through the nosles.

c, is the hole in the bottom of the cylinder

left for the boring rod, and afterwards filled up by a plate counter-sunk into the bottom of the cylinder, as shewn in the fig. 1.

d d d d, are the nosles, edged with brass, inclosing the steam ports; on these brass surfaces are to move the sliding surfaces of the valve.

e e e, is the cast-iron steam casing, or termination of the steam pipe surrounding the cylinder, and opening into the space *f*, between the nosles

f, is the steam space between the nosles, in which works the slides *gg*.

g g, is the slide which cuts the steam off when it is desired to work the steam expansively.

h h, are two ports through the slide, corresponding to the two ports *h'h'*, through the steam casing.

i i i i, are raised spaces between the ports, the edges of which are rounded, angular passages for steam being objectionable.

k k, fig. 2, is the flange to which is bolted the valve casing; *l l*, the bolt holes.

x, the projecting part of the cylinder, covering the lower steam port, which thus admits the steam to the very bottom of the cylinder.

It is easily seen how the slide *g g*, fig. 1, opens and shuts the ports *h′h′*, and thus admits or cuts off the steam; for on the throttle valve being opened, the whole space *f*, between the nosles, is filled with steam, and the space *f*, in fig. 2, being closed by an iron plate, the only outlet for the steam is through *h h*, *h′ h′*

y, is the rod which works the slide *g g*.

Figures 3 and 4 represent a plan and section of the cylinder cover.

a a a a, the flanges for the bolts to secure the cover to the cylinder, through the corresponding flanges *a a a a*, fig. 1 and 2.

b b b b, ornamental mouldings, serving to contain a quantity of melted tallow.

d d d d, the stuffing box; *e e e*, the space left for the stuffing box cover or gland to fit into; *g g*, the check on which the brass ring rests; the brass ring is bored to the exact diameter of the piston, and prevents any packing from passing below the check *g g*.

f f, are holes for the bolts, which passing through the gland, fig. 6 and 5, force it down upon the packing that occupies the space between the bottom of the gland and brass

ring, causing the piston rod to work through it steam and air-tight.

h, in fig. 4, is the space cut out of the cylinder cover, the width of the upper steam port; thus the piston, although close to the cylinder cover, receives the steam on its upper surface.

Figures 5 and 6 are a plan and section of the gland or stuffing box cover.

a a a a, is the flange corresponding to *d d* in figs. 4 and 3.

f f f f, are the bolt holes, corresponding to *f f* in fig. 3, by which the packing is screwed down tight.

b b, is the hole for the piston rod.

c, is the grease cup, into which melted tallow is poured to lubricate the piston, and keep it working steam-tight in the packing.

d d d d, the ornamental mouldings, confining the grease.

g g, is the brass lining of the gland, when not all of brass.

Figures 7 and 8. Section and plan of piston.

a a a, main piece, or boss, of piston.

b b b b, ledge on which the junk ring is accurately ground.

c c, the junk ring.

d d d d, the solid ring surrounding the hollow part of the piston, on the top of which rests the junk ring, and on the sides of which are the recesses for the springs.

e e e e, the recesses for the springs.

f f f f, holes for the bolts which secure the junk ring to the piston.

g g, hollow part of the piston.

h h, eye of the piston.

i i i i i i, ledge on which the packing rings rest, and on which they are ground steam-tight.

j j j j, the packing rings; the shaded space represents the cod, the front of which bears against a mortice cut in the ring, and the back against the spring.

l l l l, the springs (of bent steel); one of which is in each recess.

m m m m m, the strengthening pieces.

n, the hole for the cutter, which secures the piston to the rod.

Figure 9 is part of a packing ring and cod enlarged.

A, is part of the ring, shewing the joint at the segment.

a, is the mortice cut out of the ring for the cod.

b, is a tenon, fitting into the ledge *i i i*, fig 8.

jj, the packing ring and cod, the shaded space being the cod; it will be seen that no mortice is cut out of the upper ring, and that the spring does not touch it, but the mortice would be found at the next recess, and there the cod and spring found bearing against it; at which place, also, no mortice or cod would be found on the lower ring.

l, the spring, as in fig. 7.

d, part of the solid ring *d d d*, as in figs. 7 and 8.

THE SLIDING VALVE.

The sliding valve, or as from its shape, it is often called the D slide, regulates the admission of steam, above or below the piston, as may be required, opening and closing the passages to the condenser alternately; it supplies the place of the old fourway cock, and is in general use both in land and marine engines; but as the opening and closing of the steam ports and of the passages to the con-

denser, can be effected in many ways, there is no part of the marine steam engine in which so many differences are found, no two engine makers following the same plan.

I shall endeavour to describe the long slide, as it is the most generally used, and its principle applies more or less to all slides.

The slide valve is made of cast iron, and resembles a cylinder cut in half and bounded by a flat surface, the interior of the slide forming a hollow tube, and the exterior having two flat projecting faces, opposite the steam ports in the cylinder: these sliding faces are ground upon the flat face of the nosles of the cylinder, so that in sliding up and down on the brass plates formerly described, they will open and close the ports alternately, and pass over them steam tight, these faces are larger than the opening of the steam ports, so as to admit of the valve shutting both ports at once, when it is desired to stop the engine, &c., the exterior of the valve slightly projects towards the back of the valve casing, in a line with the sliding surfaces.

The body or front of the valve recedes a little from between the sliding surfaces; and

both above and below the face that covers the ports, a thickness of metal is left, on which the valve slides, corresponding to the brass plates on the nosles of the cylinder; to the back of the flat side of the valve is attached a rod, which passes through two sockets in the valve, and is secured to the lower one by a nut and screw.

The valve is enclosed in a valve casing of cast iron, which on its flat side opens towards the nosles of the cylinder. It is bolted to the flanges on them, by square headed bolts passing through corresponding flanges in itself, and has two flanges at its upper and lower edge, one for securing it to the foundation plate, the other for the bolts which secure its cover.

A hole of the same shape as the valve casing is left in the foundation plate, communicating through a short passage into the condenser. When the valve casing has been firmly secured, rusted iron filings and shavings are driven into the joints, with a caulking iron, and render the whole steam tight.

Opposite the steam ports, are two projecting spaces or collars for packing, in order that

the valve shall move up and down steam tight in its casing.

The packing consists of several thicknesses of gasket sewn together, which bear against the slight projection in the slide above mentioned; and it is forced against the slide by a packing ring of iron, which is introduced into the collar behind them, by pinching-screws passing through the valve casing, and resting with their points on the packing ring; this ring is in two parts for the sake of convenience. Nuts are screwed into holes drilled through the valve casing, and a jamming-nut on the outside prevents the pinching-pin from working slack.

A cover with a hole for the rod that works the slide to pass through, furnished with a stuffing box, similar to that on the cylinder cover, completes the slide valve case, which is thus open for the reception of steam, to the space between the nosles of the cylinder formerly described. If then the throttle valve be open, the whole space in the valve case between the packings will be filled with steam, which will surround the valve, and be hindered from passing upwards or downwards,

by the projecting faces of the valve on one side, and the packing on the other.

It is easily seen how sliding the valve up or down will permit this steam to enter the cylinder, either by the upper or lower steam port.

On one side of the valve casing is the blow-through valve, the object of which is to admit steam to pass from the valve case into the condenser, to expel air and water from it, preparatory to forming a vacuum.

A small port is cut in the valve casing, just above the lower packing, and another similar one below it, outside the valve casing, and enclosing these two ports is a valve chest, containing a flat valve of brass, attached to a spindle, which works steam-tight through the cover of the valve chest; a lever is fixed to the spindle; on lifting up the valve, the steam rushes from the valve chest into the aperture in the valve casing below the packing, and into the condenser, from whence it expels air and water through the tail valve at the foot of the air pump. We shall explain hereafter the necessity of this operation, which is called blowing through.

In many engines there is an arrangement for working the steam expansively, by cutting off the communication between the steam in the steam pipe, and that in the cylinder, when the piston shall have gone a certain distance: a very convenient and simple method of thus cutting off the steam has been adopted by Mr. R. Napier,—a slide of metal is introduced between the cylinder and valve case, in the space between the nosles; this slide works in grooves, by a rod attached to it, passing steam tight through a collar between the cylinder and valve case. The space between the nosles being closed by an iron plate, below which are two ports, the slide has also two apertures corresponding to these, so that it need move only half the whole distance it would have to travel if the steam apertures were all in one,—the space between the apertures in the slide, exactly closing the ports in the iron plate above described.

This slide has to travel, or open, twice during each ascent or descent of the piston, and its motion should be very quick; this is effected by an ingenious eccentric pulley, fixed on to the intermediate shaft; when it is not intended

to use this slide, a lever lifts its rod up, and throws it out of gear.

Figure 10 is a section of the slide valve, or long slide, and of the slide casing.

a a, is the valve casing, shewing the thickness of metal only.

b b, is the cover of the casing, furnished with a stuffing box, gland, &c. but which is not shewn, as it is nearly the same as the one described in the cylinder cover.

A, is the body of the valve, which is a hollow tube.

c c, the projecting sliding faces, which travel on the brass surfaces, *d d d d*, fig. 1 and 2, and which open or close the ports *b b b b*, fig. 1 and 2.

d d d d, called the tail of the valve, and travels on the brass plates already mentioned, corresponding to *d d d d* in fig. 2; *e* is the rod by which the slide is worked.

f, is the exterior of the body of the valve, towards the cylinder, forming a projection over the rod.

g, strengthening bars, forming sockets through which passes the rod *e*.

h, slight projection of the valve, against which the packing is forced.

i i, collars into which is introduced a packing ring.

k, the packing ring, the shaded space represents the packing.

l l, the pinching-pins by which the packing ring is forced against the packing, and that against the back of the valve.

m m m m, a small check or projection of metal in the collar, which prevents the packing from working up or down, with the motion of the slide.

n n, the jamming nut.

o, the nut working at the end of the rod.

Figure 11. is a front view of the same valve and casing, the same letters apply to this, as in fig. 10.

x, is a flange, corresponding to the flange *k k*, in fig. 2 to which it is bolted, gasket being introduced between the flanges, and a rust joint formed on each side of the brass plates, *d d*.

z z, bolt holes, by which the casing is secured to the cylinder.

THE CONDENSER.

The condenser is a large rectangular vessel of cast iron, into which the steam passes alternately, from above and below the piston, to be condensed by the injection of cold water. It has three important parts: 1st, the foundation plate; 2nd, the condensing chamber; 3rd, the hot-well and air-cone.

1st. The foundation, or sole plate, is generally, though not always, cast in one piece with the condenser, of which it thus forms a part.

It is a platform on which are secured the cylinder, the valve casing, the air pump, and the frame which is to support the shafts; it is of cast iron. Under this platform, at the cylinder end, are two raised projections, called feathers, which bear against the sides of the sleepers in the vessel's bottom; in front of the cylinder they unite, and form the bottom of the valve casing, the bottom of the condenser and air pump; they divide again after passing the air pump, leaving an open space for the cross-tail, and connecting rod; on the end of the sole plate stands the crank frame. In front of

the bottom of the air pump is the tail or blow-through valve.

The cylinder end of the sole plate has a concavity corresponding to the bottom of the cylinder, which is bolted down to it by bolts, having screws and nuts on their upper ends, and a square head below; long bolts of large diameter pass through the sole plate into the sleepers to secure it firmly to the ship's bottom.

The upper part of the sole plate rises after passing the cylinder, and receives the valve casing, which is bolted to it in the same way, and a good joint made by rusted iron borings and filings, well driven in with a caulking iron; when the valve casing it bolted on to the sole plate, a short low passage is thus formed into the condenser.

The exterior of the condenser is of an oblong form, out of it, on each side, projects the axis, on which the side levers or sway beams are to work The ends of this axis are called the main centres. In casting the condenser, a tube of metal is left for it to pass through. The main centre passes through the tube, bearing only on places left purposely on the sides of the

condenser; it is keyed or wedged in, and rusted in so as to be immoveable; on each end of the projecting axis the sway beams are secured.

Externally the hot well and condenser appear be one vessel, but internally it is seen that the roof of the condenser forms the bottom of the hot well.

A copper pipe, punctured with small holes, passes through one side of the condenser, and is secured to the other; this pipe communicates with the sea by a cock, and admits the water requisite to condense the steam, into the condensing chamber.

The quantity admitted is regulated, by opening or closing a cock, furnished with a lever or handle, terminating in some convenient place for the engineers.

As the steam enters the condenser, it is met by a jet of water from this pipe, and immediately it is turned into water, occupying a space nearly 1700 times smaller than when in a state of vapour, and forming an imperfect vacuum; a small cock communicates with the external part of the condenser, and to it a guage can be affixed, which shall denote the

degree of vacuum in the chamber; if the passages from the condensing chamber are properly constructed, there will be scarcely any difference between the vacuum in the chamber and that above or below the piston in the cylinder.

In front of the condenser, between it and the air pump, is a valve, which is sometimes in two or more parts.

The foot valve is generally of brass, standing at a small angle in a frame, to which it is connected at its upper side by a hinge joint, it can only open outwards towards the air pump, and where it closes upon its frame, the surfaces are ground accurately upon each other, so as to be nearly steam tight.

The frame itself is firmly fixed, either in the front of the condenser, or in a short passage between the condenser and air pump, according to the size of the condenser: it is so fixed as to be accessible for examination or repair when requisite.

The use of the foot valve is to prevent the return of any water, uncondensed steam, air, &c. from the air pump into the condenser; upon each lift of the air bucket the valve

opens, and admits the escape of whatever may be in the condenser, but closes on each down stroke of the air bucket.

Over the condenser, and in communication with the air pump is the hot well, into which the condensed steam, mixed with the injection water, and the air disengaged from the water in condensation, is pumped, and on the top of this hot well, is an iron cylinder forming a continuation of the hot well, terminating in a cone, called the air cone.

A pipe passes from the air cone through the ship's side, and allows the air that has been disengaged in the condensation to escape.

Some engine makers allow this air to escape into the engine room, through holes in an air vessel on the top of the hot well. As the water in the hot well has a considerably higher temperature than that on the outside of the vessel, a portion of it is returned to the boiler through a feed pipe; a forcing pump, by the side of the hot well, forces a certain portion towards the boilers, and at the end of each feed pipe is a cock by which the engineer can regulate the feed to the quantity required.

As the force-pump above mentioned can

supply more water than is generally required, an escape valve is provided, by which the surplus runs off into the waste pipe.

The hot well opens into a large pipe of cast-iron, called the waste pipe, which goes through the ship's side, as near the water line as possible. Through it passes the remainder of the hot water, as it is forced up by each successive stroke of the air pump.

The position of the feed pumps, and waste pipe is not alike in all engines, but the principle is the same; viz. a feed pipe to supply the boiler, worked by a force-pump, a waste pipe for the remainder of the water to run overboard, and a valve, either loaded or compressed by a spring, for the escape of the surplus water in the feed pipe through it into the waste water pipe.

The waste water pipe is sometimes, in loaded vessels, *below* the surface of the water; the necessity for continuing the hot well, either in its square shape, or as a cylinder, to some distance above the water line is obvious; as also of closing the top of the hot well, which otherwise in the lurching of the ship, might become considerably lower than the waste water pipe,

and fill the ship with water. I have seen one steam vessel, with her hot well open: the waste water pipe can be closed in harbour in most vessels by a large valve of brass with conical edges, fitting into a seat in the waste pipe, it can be raised or opened by a large handle bolted into it. Great care is taken in fitting the pipes through the ship's sides, so as to be perfectly tight, and to prevent any risk of the pipe's breaking from the working of the ship.

Fig. 12, represents a section of a condenser, hot well, and air cone, as also of the air pump attached to it.

A, condenser.

B, hot well.

C, air cone, which fits on the top of the hot well *B*.

D, is the air pump.

a, is the main centre.

b, the injection pipe.

c, space over which the valve casing is bolted.

d, foot valve opening towards the air pump only.

e, feed pipe, by which part of the water out of the hot well is conducted to the boilers.

f, waste water pipe.

g, a tube through which passes the starting shaft.

g′, door of man hole, by which access is had to the interior of hot well.

h, the air pipe through which the air disengaged in condensation is carried overboard.

i, is the section of an air bucket, through its strengthening feather; *d d*, without its delivery valve, the shaded spaces represent the packing required to keep it air tight in the cylinder.

k k, the raised rim on which the lifting valve rests, steam tight, the surfaces in contact are accurately ground upon one another for that purpose.

l, the eye of the pump rod, which is secured to the air bucket by a cutter passing through both.

w, is the blow-through pipe, terminating in a valve chest *x*, which should be filled with water.

x′, is the tail valve, through which the air and water in the condenser is blown out by

the admission of steam into the condenser, preparatory to starting the engine.

y y, is the foundation or sole plate, forming the bottom of the condenser, air pump, &c. &c.

z, is a strengthening feather, under the crank frame. Between *z* and *x*, is the space in which the connecting rod and cross tail work.

o o, the flange by which the air pump is bolted to the condenser.

AIR PUMP.

To prevent the condensed steam, injection water and disengaged air from accumulating and filling up the condenser, a pump, called an air pump, is resorted to.

The air pump works in a cylinder of cast iron, lined with brass or copper.

This cylinder is bolted down to the foundation plate, in front of the condenser, and is there secured steam tight, by caulking with iron borings and filings, called a rust joint.

The upper part of the cylinder, where it is intended to place the seat of the valve, projects outwards a little, and terminates in a square projection with a flange, by which it is bolted

to the condenser, and forms the communication from the valve seat into the hot well.

The valve seat is a projecting circle of cast-iron in the interior of the cylinder, on which the delivery valve is to rest.

It is secured by four or six bolts, passing diagonally through it and the sides of the cylinder.

The valve seat leaves a large open space within it for the delivery valve.

The delivery valve is a solid circle, generally of iron, with a hole through its centre for the air pump rod to pass through it; the valve is concave above, and has a collar on it, either of brass or lined with brass for the rod to play through, fitting accurately.

When the valve is down upon its seat, which is also concave, no water can return from above it into the cylinder below.

The water and air are brought up to this delivery valve by what is called an air bucket.

The air bucket is made of brass, or iron edged with brass, resembling a wheel in shape.

The sides of the bucket form a deep groove all round it, into which is firmly secured a

hemp packing, so as to render it air and water tight in the cylinder.

The centre of the bucket is hollow, and the rod passes through a conical eye, to which it is secured by a cutter passing through both.

From the eye run six strong arched radii or feathers, terminating in a ledge, on which the lifting valve is to rest.

The air pump rod has a conical end, and has two grooves for packing, so that it is perfectly water tight in the eye of the bucket.

The radii, or feathers, are concave above, and the eye of the bucket is thus lower than its sides.

On the top of the air bucket fits the lifting valve, which is also of brass, or iron edged with brass.

It is solid, and occupies the hollow space left in the air bucket, it has a hole and collar similar to those in the delivery valve for the air pump rod to pass through; its upper surface is also strengthened by radii, corresponding to those in the air bucket.

The faces of the air bucket and valve, where in contact, are ground upon one another, and

are water tight when the valve is down on the bucket.

Another common form of air bucket and valve, is that called the butterfly valve, or clack valve, and it is very generally in use.

Also, in many engines the delivery valve is placed in a short passage between the upper part of the cylinder of the air pump and the hot well; in which case it resembles the foot valve, and opens into the hot well; the valve can be easily got at in this situation to repair or examine it.

On the top of the air pump cylinder is a cover, similar, in all respects, to the cover of the steam cylinder, it has its stuffing box, grease cup, &c., and is bolted to the cylinder in the same way; but it is without its grease cock or escape valve.

In front of the air pump, and at its foot, is the tail valve or blow-through valve.

This valve is of brass, with conical edges resting on a seat, in a cast-iron pipe, which expands and forms a chest, which should always be full of water, in order to insure no air passing through it into the air pump and condenser, for it is to be remembered, that we

endeavour by all means to obtain as perfect a vacuum as possible, and the admission of air through this valve, would seriously affect the engine's power. It should frequently be looked at, for chips of wood, particles of coal dust, &c. sometimes find their way into the pipe: the pressure of the atmosphere keeps the valve shut, but it is an additional precaution to have the chest full of water.

It is as well to state here, that the air bucket works in a vacuum, unlike a common pump, and lifts the water to the delivery valve mechanically; as the bucket descends into the water, at the bottom of the cylinder, the lifting valve is raised up, and the water flows over the top of the bucket, but the moment the pump begins to lift, the weight of the water, &c. shuts down the lifting valve upon the bucket, and all that is above both is lifted up to the delivery valve, which is forced open, and receives the contents of the air bucket into the upper part of the cylinder and lower part of hot well; but here we have the whole weight of the water in the hot well, if any, and the pressure of the atmosphere, resting on the delivery valve; the moment, therefore, the down stroke

begins, the delivery valve is closed by this pressure, and nothing returns.

Thus the air pump effectually keeps the condenser free for working.

In figure 12, *D* is the air pump cylinder, the inner lines of which represent the lining of brass or copper; *b′ b′*, the flange by which it is bolted to the foundation plate.

Figure 13, is the plan of the air bucket *i*, figure 12.

The same letters apply in both figures; *k k*, the rim for the lifting valve; *d d*, the strengthening feathers; *l*, the hole through which passes the pump rod.

The lifting valve and delivery valve being similar, I have only drawn the delivery valve, figure 14.

t t, figure 12, is the cover of the air pump cylinder, with its stuffing box, gland and grease cup; *v v*, similar, in all respects, to the cover, &c. of the cylinder; the cover is bolted to a flange *t′ t′*, as is the cylinder cover.

In figure 12, *p p*, is the valve seat; 2, the bolts by which it is secured to the air pump cylinder.

m is a section of the delivery valve, through its raised feathers or radii; *n n*, is the hole through which plays the pump rod; the valve seat has a raised rim; *k′ k′* similar to *k k* on the air bucket, for the valve to rest on.

Figure 15, represents the collar of brass, or iron lined with brass, which is bolted on the delivery valve; *m*, through *z′ z′*, the hole *s* for the pump rod, is turned exactly to the size of the rod, and when the valve *m* is down on the seat *p p*, it is almost water tight.

Figure 14, is a plan of the delivery valve *m*, figure 12, the same letters apply in both figures; *s*, the hole for the pump rod; *n n*, the feathers; *z′ z′* the bolt holes.

We now come to the working parts of the engine, and the first thing to be considered are the sway beams or side levers, two of which are attached to each engine.

The sway beam is of cast-iron, eliptical on its upper and lower surfaces; it works freely on its axis, the main centre; it receives its motion from the piston, and communicates it to all the other parts of the engine.

We have described the axis passing through

the condenser, and keyed in several places, as well as rusted in. Its arms project sufficiently on each side of the condenser to allow the various rods which are attached to the inner sides of the sway beams to work freely clear of all the fixed parts of the engine; the arms are cylindrical, highly polished, terminate in a circular tenon, and are cut for a pinching screw.

In the centre of the sway beam is left an octagonal hole, which is bushed with brass, so as to be truly cylindrical; the sway beam is then shipped upon the main centre, a washer of brass, which is scored out so as to take the circular tenon in the axis, is hove taut by the pinching pin already mentioned, and below the brass bushing, through a square space left for it, is driven a cutter, by which the brasses can be tightened as they wear; an oil cup, or lubricator, is placed on the upper and inner side of the brass bushing, which is in two parts, grooved so that the oil flows through every part of the journal or joint.

Both ends of the sway beam are divided or cleft; through this division a pivot is rivetted to both sides of the sway beam, and the sides

are so cut away as to admit of the straps which work upon the pivots having play in a fore-and-aft direction.

The centres of the pivots at one end of each sway beam are nearly opposite the centre of the cylinder, to these are attached the side rods, which are to give motion to the sway beam. Other pivots are attached to different parts of the sway beam to work the parallel motion rod, the feed and bilge pumps, and the side rods for the air pumps. In all marine engines the sway beam has to do this work, though its motion is taken off very differently in some engines, according to the fancy of the maker.

The pivot at the end of the sway beam receives the strap of the cross-tail or fork-head, by which motion is communicated to the connecting rod, and thence to the crank.

The side rods, or cylinder side rods, to distinguish them from the air pump side rods, are connected with the piston rod by a cross-head.

The cross-head is a mass of wrought-iron, considerably deeper than it is wide, through the centre of which a hole is bored for the piston rod to pass through; the end of the rod has a screw cut on it, and is firmly secured to

the cross-head by a large nut working on the screw, and by a cutter passing through both the rod and the cross-head.

The cross-head forms a parabolic curve on its upper and lower surfaces, and terminates in two conical arms, which are turned with great care, leaving a considerable shoulder at their inner ends, and having their smallest diameter at the outer end; these arms receive the pinching pin, and have fitted upon them a conical bushing of brass, with the large diameter outside.

On the arms of the cross-head so fitted, the side rods are shipped, leaving the arm projecting through the side rod; a hemispherical cap of iron fits on to the projecting end of the brass, a pinching pin passes through this cap, and forces the brass sufficiently tight upon the arm of the cross-head; as the brasses wear, by turning the pinching pin, they can be fixed at any degree of tightness required; the head of the side rod forms an oil cup, and is pierced so as to allow the oil to penetrate the brass.

The side rods are cylindrical bars of wrought iron, their upper end terminates in a hollow

sphere, through which passes the arm of the cross-head, as we have just described; the lower end terminates in a rectangular shape, which fits into a strap round the pivots in the ends of the sway beams.

The strap is of wrought-iron lined with brass, which is moveable, and in two hemispherical pieces; the edges of the brass overlap the iron of the strap; the brass is driven into the lower end of the strap, which is then put round the pivot, turned up, and the other half of the brass fitted in. The heel of the side rod butts against this brass, fitting in between its overlapping edges, and exactly filling the space between the horns of the strap; a rectangular hole is cut in the side rod, and a corresponding one through the strap; through these holes pass a gib and cutter, which secure the side rod to the strap, and set up the brasses as they become worn; the gibs are flat pieces of iron, larger at one end than the other, and terminating at each end in a projecting notch; this projection is turned opposite ways when there are two, and a long wedge of iron, called a cutter, passes between them, and is driven to the required

tightness, the whole forming a wedge in three pieces; the cutter is prevented from moving by a forelock or pin at the small end.

But though the side rods are attached to the cross-head of the piston rod, and thus ought to move up and down in vertical straight lines as the piston rises and falls, yet they are also attached at their lower ends to the sway beams by the strap above described; now, as the sway beams, turning on their axes, describe a segment of a circle, it is evident that the side rods would be pulled or thrust out of the vertical line, and through the cross-head would communicate that lateral pull or thrust to the piston rod, which would either cause it to bend or insure a leak in the stuffing box in the cylinder cover; a contrivance is necessary to avoid this, and guide the cross-head in the vertical line, in which alone the piston can move. From the nature of the apparatus used to effect this purpose in land engines, it was called

A parallel motion.

For this purpose, at some distance from the cross-head, but parallel to it, is a cylindrical iron bar resting upon, and free to revolve in

plomer blocks, which are secured to the frame of the engine; this is called a radius shaft, or motion shaft.

The motion shaft is made to perform a half revolution in the direction opposite to that which the side rod would take from the thrusting or pulling of the sway beam. This motion is given to the radius shaft by rods called parallel motion rods, which are connected at their lower ends to the sway beams near the main centre by a strap, gib, and cutter, and, at their upper ends, to a short lever at right angles to the radius shaft.

To these levers are also secured the radius bars, which are rods of wrought-iron, proceeding from the side rods; they are connected to the side rods by a sort of crutch, in which the side rod works, a pin passing through the crutch and side rods; the journal is provided with grease cups and bushed with brass.

These radius bars, in some instances, go direct to the heads of the side rods; in others, they are attached at different parts of the length of the side rod, depending on the position of the parallel motion shaft, &c. &c.

Figure 1, plate 2, is the sway beam.

a, is the main centre.

b b′, are the pivots; on *b* works the strap which connects the cylinder side rod to the cross-head of the piston; on *b′* works the butt end and strap which connect the cross-tail to the sway beam.

c′, is a pivot, on which works the air pump side rod.

d′, a pivot working the feed pump on the inside of the sway beam, and a bilge pump on the outside.

ė, is a pivot working a bilge pump on the outside of the sway beam; and on the inside working the parallel motion rod.

f, is, in this arrangement, a spare pivot.

g, a square projection, containing a cutter, *h*, which presses against the brass bushing *j*, and tightens the journal as it wears; *k*, the brass washer and pinching pin.

Figure 2 is a piston rod.

a, is the head of the rod where it passes through the cross-head.

b, the conical eye, or end of the rod, which goes through the eye of the piston.

c, the cutter by which it is secured.

d d, two grooves made in the rod to receive packing.

e, mouldings.

g, nut which works on the end of the rod, and secures it firmly to its cross-head.

Figure 4 is a cross-head.

a, the hole for the piston rod; *b b*, the arms; *c c*, the shoulders, against which the side rods bear.

Figure 5 is a plan of a cross-head; the same letters apply as in fig. 4.

Figure 6 represents a section of the brass bushing for the arms of the cross-head; *a* representing the thickness of the brass, *b* the arm on which it is fitted, and *c* the shoulder against which it rests.

Figure 7 is a plan of fig. 6, the same letters applying; *e* is the hole in the arm *b*, for the reception of the pinching pin.

Figure 8 is a section of the cap and pinching pin.

g, is the pinching pin; *f*, the cap; *h h*, the part of the cap which bears against the brass bushing *d*, in fig. 6.

Figures 9 and 10 are two views of a cylinder side rod—a front and side view; the same letters apply to each.

a, is the head of the side rod bored out for the reception of the arm of the cross-head.

b, is the rectangular termination of the lower end, fitting into the strap *c c c*.

g g, are the gibs.

h, the cutter by which the side rod is secured to the strap.

d d, the brass bushing of the strap.

e, the end of the rod bearing against the bushing *d*; the brasses are tightened by driving the cutter *h*.

In fig. 9, *f* is the hole for the gib and cutter; *l l*; the lubricator, or oil cup; *k*, the hole through which is pinned the radius bar.

Figures 11, 12, and 13, represent a strap, gib, and cutter.

c c c, being the iron strap; *d d*, the brass bushing, in two parts; *a*, the space in which the pivot works; *f*, the rectangular hole for the gib and cutter.

In fig. 13, *g g* are the gibs, and *h* the cutter.

Figure 14 is a diagram of the parallel motion, as described above.

C, is the centre of the motion shaft; *C D*, is the short lever, at right angles to the motion shaft; D, D^1, D^2, being the point to which

the radius bar $P\ D$, is attached, and the point also to which is attached the parallel motion rod, $D\ E$.

A, is the main centre; $A\ B$, the position of the beam at half-stroke, horizontal, the radius bar PD, being also horizontal.

AB^1 and AB^2, the position of the beam at the end of the stroke, the beam vibrating in the arc B^1, B, B^2.

P^1, P, P^2, is the direction in which the piston rod moves vertically.

BP, the side rod, P being the joint to which the radius bar PD, is attached; B, the point attached to the beam. The path of the point P ought to be in a vertical line.

The parallel motion rod, DE, communicates the motion of the radius, AE, to CD, causing it to perform an arc of a circle, D^1, D, D^2; the radius bar, attached to the point P, thus keeps it nearly in the vertical line P, P^1, P^2; P^1 and P^2 representing the terminations of the stroke.

Thus, although B^1 and B^2 follow the segment of the circle described by $A\ B$, the point P, to which the radius bar is affixed, is compelled by it to keep nearly in the straight line

P^1, P, P^2; in practice, the deviation from a straight line is not perceptible, all the parts having just sufficient play to counteract it.

Let us now explain shortly the way in which the radius bars act. The motion shaft is generally so placed as to insure the radius bars being horizontal at half-stroke, or parallel to the beam. Whatever thrust or pull is communicated to the lower end of the side rod by the sway beam, is resisted by the radius bar at the other end of the side rod, and the path of the point to which the radius bar is attached is kept in a vertical straight line, or nearly so, for, strictly speaking, it performs a curve of a very high order. The principles of this invention, and full details as to the most advantageous method of effecting this vertical motion, will be found in Tredgold's work.

It has been explained before, that each end of the side rod has free play in a fore-and-aft direction on its respective journals.

It is also common to find the side rod at its upper end bushed with brass, and fitted on to the arm of the cross-head, where it is secured by a cutter driven through a recess in the lower brass, by means of which the requisite tightness of the journal is preserved.

THE FORK-HEAD OR CROSS-TAIL.

The cross-tail is of wrought-iron, connects the ends of the two sway beams together, and communicates their motion to the connecting rod, which is secured to it.

The cross-tail, in shape, resembles the cross-head of the piston, only it is considerably larger and stronger.

The arms of the cross-tail are cylindrical; a butt end is secured on them, being driven on hot and keyed, and fixed in its place by a circular iron cap, which screws on the end of the arm of the cross-tail

A butt end is a stout short piece of wrought-iron, which connects each end of the cross-tail with the pivots in the end of the sway beams. It has a circular hole in it for the arm of the cross tail to pass through, and terminates in a square butt, which fits exactly between the horns of the strap, close up to the brass bushing of the strap; the strap is precisely similar to the one already described as connecting the side rods with the sway beam, provided in the same way, with gib and cutter, lubricators, &c., &c.

Through the centre of the cross-tail a large conical hole is bored for the end of the connecting rod, which is driven through it, and secured by a large nut working on a screw cut on the end of the connecting rod.

Figure 15, *A* and *B*, are butt ends.

a, the hole for the arm of the cross-tail; *b*, the rectangular end fitting into the strap; *c*, the hole for the gib and cutter.

Figure 16, *A* and *B*, are two views of a cross-tail.

a a, the arms for the butt end; *b*, the hole for the connecting rod; *c c*, the caps which secure the butt end on the arms; *d d*, the screw on the arms.

The connecting rod is a large cylindrical bar of wrought-iron, which is secured to the cross-tail, as above described, at one end, and at the other end terminates in a square, fitting into a strap round the crank pin, which strap is similar to those already described; it is secured to the strap by a gib and cutter.

Figure 17, *A* and *B*, are two views of a connecting rod.

a, is the strap; *b*, the hole for the crank pin; *c*, the head of the rod.

The air pump rod has secured to it a cross-head similar to the piston end; two side rods are attached to this cross-head by the same sort of journal we have described for the cylinder side rods; the ends of the side rods work on pivots (rivetted through the sway beams), by a strap, and are secured with gibs and cutters, provided at their respective journals with lubricators for the brasses; the rods and cross-head are smaller in size than those belonging to the piston rod.

It is also very usual to see two plungers attached, one on each side of the cross-head of the air pump; one works a bilge pump, the other the feed pipe. The cross-head works on guides, which answer the purpose of keeping the air pump rod vertical without resorting to a parallel motion.

The shafts are now to be described; they are the axes which are to turn the paddle wheels, and I shall begin by saying, there are three of these axes or shafts—the intermediate, and the two paddle shafts.

The intermediate shaft is a large axis of wrought-iron, which rests on the main plomer blocks on the frame of the engine. It is of greater diameter in the centre than at its extremities, and truly cylindrical where it rests on its bearings.

On each extremity of the shaft is fixed a crank, and they are at right angles to each other, to enable the engine to turn its centres with facility.

There are two slightly raised shoulders on the shaft on each side of the plomer blocks, where it turns in its bearings, and the arms of the shaft outside of these bearings are left conical for the crank. Two other slightly sunk spaces are left on each side of the plomer blocks on the shaft as journals for the eccentric pullies; a space is also cut out of the shaft, into which is bolted a semicircular catch of iron, projecting from the surface of the shaft, and tapered at a certain angle so as to lock with a corresponding catch on the eccentric pulley.

The cranks are large pieces of wrought-iron; there are two fitted on to each intermediate shaft at right angles to each other, and one to

each paddle shaft, parallel to the corresponding crank on the intermediate shaft: they connect the two shafts by the crank pin.

There is a conical hole in the shaft end of each crank, which is considerably larger than the other; the crank is driven on the shaft red-hot, and, contracting in cooling, is firmly fixed there, besides which, a wedge-like space, two or three inches wide, is cut out of the intermediate shaft, and a key, or long wedge of iron, driven firmly into the space, and rusted in. The other ends of the cranks on the intermediate shaft have a circular hole bored through them for the end of the crank pin, and a small conical hole is punched through the thickness of metal for a forelocking pin to pass through the crank into the crank pin, like the pin in the shackle bolt of a chain cable.

The crank on the paddle shaft being secured, as before described, the other end is bored conically, into which a brass bushing is secured, and, finally, a crank pin, which is conical, and of great size, is driven from the paddle crank into the intermediate crank, and secured by a forelocking pin as before described.

The crank pin is of wrought-iron, and has a slight depression between the cranks, forming a journal for the strap of the connecting rod.

The paddle shafts are the axes to which the wheels are secured; we have described their connexion with the intermediate shaft. Their inner ends are cylindrical, and rest on plomer blocks on the outer frame of the engine; their outer ends are also cylindrical, and rest on plomer blocks on the lower part of the paddle-box, supported by a short strong piece of timber secured to the paddle beams; where the paddle shaft passes through the ship's side, there is a leak box, and a pipe conveys any water that may find its way in down to the well. The bearing on the gunwhale is packed. Three spaces are left square on the paddle shaft; they are for the centres, to which the paddle arms are to be fixed.

The centres, in large wheels, are three in number, of cast iron, like the nave and spokes of a wheel.

They are driven on to the square parts left in the paddle shafts, and are there firmly keyed on each of the four faces of the shaft; sometimes a circular hollow space is left in the

centres between the keys, which is filled up with pieces of iron cast to the required shape; care is taken in securing the centres, that they shall be central to each other and to the shaft.

Into these centres are driven the paddle arms; flat bars of wrought iron, presenting their edges to the water, the ends of the paddle arms pass through the centres, being cut away into a wedge-like shape for that purpose, and are keyed there.

Two or more rings of wrought iron, secure these paddle arms to each other, they are in segments of circles, and present their edges to the water when the wheel is vertical, they are clamped and bolted at their various joints to the paddle arms, and keyed there; the outer ends of the paddle arms, terminate in a short *L* shape, the outer ring is clamped and bolted to this projection, and keyed as well.

The paddle boards or floats, are bolted on to the paddle arms, in a common wheel, by a curved bolt, which hooks on to the paddle arm, and passing through the float, is hove taut by a nut working on the end of the bolt, which is cut into a screw; a small iron washer is under-

neath the bolt; the floats can thus be easily shifted; there are generally two bolts to each paddle arm.

A common variety of the above wheel, consists in having the depth of the float divided into two or three parts; one narrow, the other wide; and in securing the upper float, *above* the paddle arms, the middle one underneath, and the third on a projection, either wrought with the outer ring, or bolted on to it, still further over or towards the next paddle arm.

This kind of wheel differs from the cycloidical wheel, as the floats of the latter are put on at angles which differ from each other; though in the cycloidical wheel the float is divided into three.

It is generally agreed, that a wheel of the two latter kinds offers considerable advantages in a heavy sea, and when a vessel is deeply immersed in the water; but all other things being alike, viz. immersion, diameter of the wheel, width of float, &c. &c. in smooth water, it is not found that any thing is gained in speed over the common wheel.

Much, however, of the disagreeable vibra-

tion caused by the common wheel is done away with.

Figure 26 is part of a wheel, shewing a centre, paddle-arms, rings, and the different float boards commonly in use.

A is the centre, fitted on to the square places left on the paddle-shaft, and keyed on each of its four faces *a a a a*.

B B, &c. are the paddle arms, passing through sockets *b b b b* in the rim of the centre, and keyed or forelocked there; *c c c* the part of the arm that passes through.

C c c the paddle ring, to which the paddle-arms are clamped and keyed; *d d d d* the clamps, *e* the bolts which secure the clamps to the ring, between each clamp and the paddle arm are one or more keys.

D D, &c. is part of the outer ring, *f f f* the end of the arm bolted to the outer segment or ring.

E is the common float, attached by two bolts *o o* to the arm.

F is a variation, by dividing the float into two pieces, one wider than other, secured to the arm in a similar way to the float *E*.

G is the float divided into three pieces; two of which are secured, as *E* to the paddle-arm, and the third, to a short projecting arm bolted on to the outer segment as *q*.

Figure 18 is an intermediate shaft.

a a, the bearings where the shaft revolves in the plomer blocks.

b b, the arms on which the cranks are fixed at right angles to each other.

c c, the bearings for the eccentric pulleys.

Figure 19, *A* and *B*, are two views of a crank.

a, being the hole for the arm on a shaft; *b*, the mortice cut out for the key.

d, the hole for the crank pin; *e*, the conical bushing of brass fitted into the hole *d*, for the crank pin.

Figure 21 is the paddle shaft.

a, the arm on which the crank is driven.

b, the bearing where the shaft revolves in the plomer block; *c c c*, are the spaces left rectangular for keying the centres which are secured there.

d, is the outer bearing for the plomer block on the outside.

The plomer blocks are sockets, in which all the shafts or axes, used in the engine, revolve.

The chief, or main plomer blocks are four, two for the intermediate shaft, and two for the paddle shafts.

They stand on the frame of the engine, at its highest point, called the crank frame.

They are of cast iron, in two parts, the lower part being firmly bolted to the crank frame, into which it is countersunk, and accurately fitted; the upper part, or cover, fitting over the lower: by the sides of the circular space, left for the shaft, are two hollow spaces for the bolts to pass through, which secure the cover in its place; the bolts are large, square-headed, put in from below; their ends receive a large nut by which they are hove sufficiently taut, and the upper part of the cover receives a lubricator to keep the journal well oiled; the circular space left for the shaft is bushed with strong cast brass; this bushing is in two pieces, and the upper one is pierced and grooved for oil.

All plomer blocks are of the same nature, but smaller according to the size of the shaft, with the exception of the outer plomer blocks for the paddle-shafts.

For these plomer blocks a stout frame of iron is cast, which is bolted on to the beam, resting on the two paddle beams, and forming the lower part of the paddle box; the brass-bushing in this is in two parts; but underneath, or above the bushing, as the case may require, there are a number, twelve or fifteen, moveable flat iron plates, by which the due adjustment of the shaft to the horizontal line can be effected. By the sides of the journal are grooves, into which a key is driven, and the iron plates secured from moving.

Figure 20, is a main plomer block.

a, is the pedestal, which is dovetailed upon the frame of the engine.

b b b b, the heads of the bolts by which it is confined to the crank frame; *c*, the bearing in which the arms of the shafts revolve.

d, the cover.

e, the hollow grooves, containing the large bolts, which secure the cover and upper bushing of brass upon the lower, these bolts are four in number, two on each side of the bearing; they are square-headed, put in from below,

the covers secured by the nuts *q q*, working on the head of the bolts.

h, is an oil vessel to lubricate the journal.

THE ECCENTRIC ROD, PULLEY, GEAR, &c.

The eccentric pulley is a circle of cast iron, cast in two pieces for the convenience of putting on it the intermediate shaft, the shaft does pass not through the centre of the pulley, but very much out of it.

It consists of two circles, one within, or standing on the other, one much larger than the other; the small circle fits on the journal of the intermediate shaft already described, on it a projecting catch is cast, to correspond to the catch on the intermediate shaft, and of sufficient length to admit the pulley to move a half revolution on the shaft, before it shall lock with the other end of the catch, on the shaft

The object of allowing the pulley to make a half revolution, is to enable the slide valve to be worked by the pulley, when the engine is backing or the shaft revolving, in the opposite direction.

The eccentric pulley is grooved for the eccentric hoop to work on, and ground smooth and polished, a counter balancing weight to its long diameter is bolted to the pulley, consisting generally of two circular plates of thin iron, one on each side of it.

The eccentric hoop surrounds the eccentric pulley, and works in the groove above mentioned; it is lined with brass, polished smooth, in two semicircular pieces, which are connected together by a nut and screw on each side of the pulley, the hoop allows the pulley to revolve in it freely, but fits sufficiently tight to be carried backwards and forwards by it in its revolution ; a long rod passes from the lower part of the hoop to the arm that is to work the slide valve.

These rods are of various kinds, but should be of considerable strength.

In this case the object of the eccentric is to cause the D slide to rise and fall at the required moment, by which the steam is admitted alternately above and below the piston.

As the shaft in performing a revolution carries the eccentric pulley with it, it will easily be understood how the eccentric pulley,

when its longest diameter is towards the cylinder, forces the eccentric rod to its nearest approach to it, and when the long diameter is on the other side of the shaft, or away from the cylinder, it will have dragged the end of the rod as far as possible from it.

The motion of the end of the rod will thus alternate backwards and forwards.

In the end of the rod is a notch, called a gab.

In describing the slide valve, we mentioned it was worked by its rod, we shall describe how.

At a short distance from the valve casing, and resting on small plomer blocks on the frame of the engine, is a shaft or axis, called a weigh shaft; on the centre of this is secured a short straight arm or lever, called a valve lifter, at right angles to the shaft, and sufficiently long to plumb the end of the rod of the slide valve, to which it is connected by a clutch and links.

The clutch is a short iron bar, secured to the end of the valve lifter by a cap and pinching screw, having two conical arms, on which the links have free play in a fore-and-aft direction.

On the head of the rod a similar bar is secured, and the two are united by the links.

The links are flat bars of iron, having a bearing in each of their ends, bushed with brass, furnished with lubricators for the arms of the clutch to work in.

As the end of the valve-lifter performs a segment of a circle, the links yield to the lateral pull or thrust, but only in an imperfect degree, and many makers use a small parallel motion, by which all strain of the rod in the collar of the valve cover is avoided.

The two brasses in the links can be set up as they wear, by a gib and cutter, which passes through links bearing upon the brasses.

On the way-shaft above described, at its inner end, is secured a short lever, called an eccentric *gab* lever, it is not at right angles to the shaft, but nearly at right angles to the eccentric rod; at its termination is a button or stud, which fits into the notch of the eccentric rod.

Besides this lever there is another one at the other end of the weigh shaft, to which a large weight is attached, as a counterbalance to the weight of the valve; this lever is called the

back-balance lever, is at right angles to the shaft, and in the opposite direction to the valve lifter; all these levers are put on the shaft hot, and further secured by pins passing through the lever and shaft; now it is evident that as the intermediate shaft revolves, it carries round with it the eccentric pulley; the eccentric rod pulled backwards and forwards by means of the valve lifter, lifts up or lets down the slide, when the slide is up, admitting steam above the piston, and when it is down, sending the steam below it.

As the counterbalance is supposed nearly to balance the weight of the slide, the strain on the eccentric or hand gear is not considerable.

When the eccentric is in gear, that is, when the notch in the rod is engaged, with the stud on the gab lever, the engine works itself, but at starting, or stopping, or wishing to reverse the motion of the paddles, the admission of steam must be regulated by hand.

For this purpose there is another weigh shaft, called a starting shaft, having on one end of it a short lever like the valve lifter, which passes through the upper end of a short bar, called a back balance link, or a link; it works through

this link, which is cut away above and below to admit of its forming a segment of a circle; the other end of the link, similarly divided, receives the end of the back balance lever before described; thus any motion communicated to the starting shaft, communicates an opposite motion to the valve lifter, that is, if you raise the lever on the starting shaft, you depress the valve lifter, and vice versa; a long bar, called a starting bar, descends nearly to the floor of the engine room, and by means of this the engine is started by hand, backed or stopped as may be required; by an ingenious contrivance of Mr. Napier's, unnecessary here to describe, this bar is shipped or unshipped at a moment's warning, without the slightest difficulty.

The contrivance by which the eccentric rod is thrown in and out of gear, is also very simple and ingenious; in most engines it is the same, and one look will be sufficient for any one to understand it.

All slides are not worked exactly in this way, but nearly all are worked by eccentrics; the principle of which is the same, and though the

starting apparatus may be different, yet some apparatus is always requisite, and it resolves itself into a system of leverage.

The ends of all the shafts, where they work on their plomer blocks, are always turned carefully, and a lubricator placed over each journal.

It may not be amiss to describe in this place the action of the slide, and the position in which the eccentric pulley is fixed on the intermediate shaft.

In describing the long slide, it was said that the sliding faces were considerably larger than the ports which they covered; the object of which is two-fold, the one to close both ports at once when wishing to stop the engine, the other to enable the slide itself to cut off a portion of the steam before the stroke is completed; the advantages of so doing, especially with strong steam, or steam much above the atmospheric pressure, have been pointed out in the preliminary chapter.

It will be recollected, that on opening the throttle valve, the space between the sliding faces of the long slide is filled with steam,

which cannot pass beyond them, till the slide, by moving up and down, opens the steam ports of the cylinder.

And it is plain, that eduction or communication between the cylinder or condenser, will take place from the upper port, when the upper edge of the sliding face falls below it; and that induction, or the admission of steam into their cylinder, will take place through the upper port, when the lower edge of the sliding face passes above it.

It is also clear that eduction will take place from the lower port, when the lower edge of the sliding face has passed above it, and that induction will take place through the lower port, when the upper edge of the sliding face shall have fallen below it.

When the valve lifter is horizontal, both ports are shut, and no communication exists between the cylinder and the condenser, or the cylinder and steam.

That part of the sliding faces projecting beyond the depth of the port, is called the cover, and is much greater on the steam side of the port than on the eduction side.

The steam side of the upper port is its lower side, and of the lower port its upper side.

Now we will suppose the depth of the steam ports to be $5\frac{7}{8}$th. inches each, and the depth of the sliding faces to be ten inches each; the cover on the steam side of each port would be three inches, but on the eduction side only $1\frac{1}{8}$th. inch.

The object of this difference in the cover is to shut the steam port before the eduction port, leaving the expansive power of the steam, already in the cylinder, to finish the remainder of the stroke.

If the sliding faces were equally projected on each side of the steam ports, or if the cover on the steam and eduction sides were equal, the eduction at one end, and the steam at the other, would open at the same time, and for equal spaces

But an aperture, which is amply sufficient for induction, would be too small to give the least effect to the eduction, the ports are, therefore, cut to a size sufficient to give the best advantage to the eduction, but by means of the unequal cover, while the eduction port is

wholly opened, the port which admits the steam is only partially so.

Let us take the instance named above, and suppose it be desired to admit steam above the piston, or through the upper port.

By means of the starting bar, the slide is raised three inches and a fraction, till when no steam can enter; but when the slide has been moved $1\frac{1}{8}$ in and a fraction, the lower port is open to eduction, and if there were steam at this moment below the piston, its condensation would commence; and by the time the upper port has opened for steam, the lower would have opened $1\frac{7}{8}$ in. for eduction; let the slide be moved up till it has fully opened the eduction side; it will have travelled $5\frac{7}{8}$ inches, + $1\frac{1}{8}$ inch, or 7 inches; but as the cover on the steam side was 3 inches, the upper port will only be opened 4 inches

On reversing the motion of the slide, that is sending it down, the steam will be cut off when the slide has travelled four inches, but the eduction will remain open till it has travelled $5\frac{7}{8}$ inches; when the slide has travelled an inch and $\frac{1}{8}$th more, it will be in the position first described; another inch and $\frac{1}{8}$th

opens the upper port to eduction; one inch and $\frac{7}{8}$ths more allows the steam to enter below the piston: it is thus seen that the steam on one side of the piston is in progress of being got rid of before the admission of steam on the other side; the motion of the piston is thus gradually retarded, prior to its change of direction.

This management of the valve we have supposed to be by hand, but it remains to see what is to be the position of the eccentric pulley, relative to the crank when in gear, to effect a cutting off of the steam at a certain portion of the stroke, and to regulate the lead, if any, the steam is to have.

When the piston is at the bottom of the cylinder, the crank will be vertical, pointing upwards; and supposing it is intended that in this position the lower port shall be $\frac{1}{8}$th of an inch open for steam, what is to be the position of the long diameter of the eccentric, which regulates the position of the valve? If it were required to have the valve lifter horizontal when the crank were vertical, the long diameter of the eccentric pulley would have to be nearly at right angles to the eccentric rod, and consequently, whatever angle the eccen-

tric rod made with a horizontal line, the long diameter would make the same angle with the crank, and when it is required that at the moment of the crank's being vertical the steam port shall be $\frac{1}{8}$th of an inch open, the valve lifter must be moved 3 inches and $\frac{1}{8}$th, and the long diameter of the pulley must be moved through a space sufficient to effect this; depending on the throw of the eccentric and the length of the travel of the valve, or the length of stroke of the valve.

In the case we have been supposing the travel of the valve was 14 inches.

The throw of the eccentric is the difference between the circumference of the eccentric circle and the shaft, or the difference of their diameters.

The throw of the eccentric depends on the length of stroke of the valve, and of the two levers that work it; the rule to find the throw of the eccentric, the length of the levers being given, will be found in the last chapter of this book; but if the gab lever and the valve lifter were the same length, the throw of the eccentric would be exactly equal to the travel of the valve.

The more the force of the steam exceeds the pressure of the atmosphere, the greater may be the cover on the steam side.

Wooden rods accurately marked to the length of the slide, the depth of port, &c. are furnished to the engineers of steam vessels, by which the amount of cover, and the position of the valve, during any portion of the stroke, may be ascertained at once.

Figure 22, is an eccentric pulley, with its counterbalancing weight to the long diameter.

a the place for the intermediate shaft.

b the long diameter of the pulley.

c the flat disk of iron forming a counterbalance to the weight of the long diameter; of these there are two.

Figure 23, is the weigh shaft, and valve lifter, by which the slide valve is worked.

a is the shaft.

c the back balance lever.

b is the valve lifter to which the rod that works the slide is attached by a clutch and links.

g, is the cap and pinching pin, by which the clutch is secured to it.

e, is the gab lever and stud.

f f, the bearing on which the shaft works in its plomer blocks.

Figure 24, *A* and *B*.

A, is the clutch and links united, and *B* is a front view of the link.

a a, are the arms of the clutch.

b, the hole for the reception of the valve lifter.

d, is the head of the valve rod, secured in a cross-head *e*, by the nut *f*.

g g, are the spaces for the cutter, by which the brasses are set up.

In fig. 24 *B*, *a* and *e* are the holes for the arms of the cross bars *a a* and *e e*.

g, is the gib and cutter.

Figure 25, is the eccentric hoop and part of the rod.

a a, is the hoop in two parts, united by the bolts *g g*, working with a nut and screw.

c, is the place for the intermediate shaft.

d d, part of the rod.

I have not given any diagram of the starting shaft, bar and gear, generally, as it is perfectly different in all engines, and easily understood by a glance at the engine itself.

Figure 2, plate 2, is a diagram showing

the working of the eccentric, and the method of setting the valve.

A, is part of a cylinder, showing the two steam ports, *a a*.

B, is part of the sliding valve, the shaded spaces *b b*, representing the position of the valve when shut, at which time the valve lifter *D c*, is horizontal.

D, is the centre of the weigh shaft, which works the valve; *g*, the gab lever; *c*, the valve rod.

The travel of the valve is 14 inches from *d* to *c*, and the travel of the gab lever is 11⅓ in. from *d* to *c*, the throw of the eccentric from *o* to *r*, is 11⅓ inches.

x, is the intermediate shaft, *H H'*, represent the centre line of the crank vertical, *xn*, *xp*, *xg*, *xr*, *xv*, represent the different positions of the long diameter of the eccentric, as the shaft revolves from *n* to *r*.

o r, being the whole motion caused by the eccentricity, and being equal to the chord of the arc *c d*, performed by the gab lever, a portion of *o r* must be cut off by the eccentric pulley, equal to the space *c* moves through, to leave the port ⅛th of an inch open for steam, at the moment the crank is vertical.

By moving the long diameter of the eccentric to *p*, the eccentric circle cuts off *o m*, equal to *c′ f′*, the path of the eccentric rod being supposed to be in the line *c′ o*, *xp* will then be the position of the long diameter of the eccentric, when the crank is vertical, and the catches will be fixed so as to lock in this position.

When the long diameter of the eccentric is at *n*, the valve will be at its lowest position, the sliding faces, *w w*, representing the upper part wholly open to eduction, and the lower port partially open for steam.

The lower port will continue open for steam, till the eccentric has revolved from *n*, to beyond *p*.

When the eccentric has reached *q*, the gab lever has been moved from *c′* to *e′*, and the ports are both closed; the sliding faces being at *b b*, as the eccentric moves from *g* to *q*, at the point *v*, the upper port is just opened for steam, at *v*, the valve is at the top of the stroke, and both at *v* and at *n*, it will be seen that a considerable motion of the shaft gives but little motion to the eccentric rod, so that the ports are kept nearly at the same opening

for some portion of the stroke; so when the eccentric has moved past 1, the port is just closed, the space from *V* to 1 representing the period during which the port is open for steam.

Although it is plain that the path described by the point *o* is not a straight line, it may be assumed as such for practical purposes, whatever motion the eccentric communicates to *c*′, *c*′ gives to *D C*, and *D c* to the valve, so while the rod moves from *c*′ to *f*′, the valve lifter moves from *c* to *f*; when the rod moves from *f* to *d*, the valve lifter moves from *f*′ to *d*′, causing the valve to rise, &c. &c.

FEED PUMPS, AND BILGE PUMPS, &c.

The engine supplies itself with water by a pump communicating with the hot well, called a feed pump.

A large pipe of cast iron communicates with the hot well, in this is placed a valve, called from its shape the horse shoe valve, which opens outwards from the hot well, and closes against anything returning into it; in

front of the valve is a sort of door, by taking off which access is obtained to the valve; at right angles to this pipe is a pump box of cast iron, in which works a brass plunger

This plunger, secured to a rod with a short cross-head, is worked by two side rods, one from each side of the sway beam, close by the main centre; the side rods are connected to pivots on the beam by the usual strap, gib, and cutter.

The feed pipe, or the pipe which is to convey water to the boiler as it is expended, proceeds from the foot of the pump box above described, and has two valves in separate boxes, the one loaded, the other not.

As the plunger descends, the water in the pump box, pressing against the horse shoe valve, closes it, and forces open the foot valve in the feed pipe; when the plunger rises, it opens the horse shoe valve, and fills its pump box, while the foot valve in the feed pipe closes by the weight of water above it, &c.; thus the water is forced onwards to the boiler by each successive stroke of the plunger, till it arrives in the boiler.

But when the cock at the end of the feed

pipe is partially shut, which is generally the case, the feed pipe, becoming full of water from the boiler to its foot valve, cannot contain any more; the water still driven by the plunger, and passing under the foot valve, goes on to the loaded valve, which it forces open, and returns by an escape pipe into the waste water pipe, already described.

The wad upon the escape valve will be always sufficient to enable the feed to overcome the pressure of steam in the boiler, but no more.

In all engines the principles of a feed pump are much the same, though the arrangement is often different.

In some engines the hot water is driven by a force pump into a stand pipe, or upright pipe, by the side of the waste steam pipe, and accumulates till its weight is sufficient to overcome the pressure in the boilers; a small escape pipe is provided, instead of the loaded valve, by which the waste water runs overboard, when it has reached a certain height.

BILGE PUMPS

Are differently worked in different engines; on Mr. R. Napier's construction, there are two worked by each engine.

The rods that work them being attached to pivots, one on each side of the main centre, by the usual strap, gib, and cutter; the box is generally iron lined with brass or copper, the bucket brass packed with hemp, a suction pipe with a valve in each, communicates with each pump, and they deliver into a common vessel, whence a pipe conveys the water overboard; the ends of the suction pipes are furnished each with a rose, to prevent the intrusion of substances that might choke the pumps, or cause a leak.

In most other engine makers' vessels, I observe but one bilge pump, worked by the cross-head of the air pump as above mentioned,—the more pumps the better.

Should the water in the vessel accumulate from leakage, shipping, seas, &c. there is a method of working the engines by injecting

the bilge water to effect condensation, instead of using the water from outside; but this should never be resorted to, save in the last extremity, as it ruins the air pump, valves, &c. from the quantity of coal dust, dirt, &c. always existing in the bilge water.

Another pump is placed by the side of the engine, which can be connected with it if desired; it communicates with the sea, and can also be worked by hand, to fill the boilers, wash decks, or act as a fire engine; this pump is generally a lift and force pump, and delivers both on the up and on the down stroke; by means of an air vessel attached to it, it pours out an uninterrupted stream.

On each side of the engine room, close by the fires, there are generally pipes with cocks, communicating with the water outside, so that remedies are at hand against fire.

The water that supplies the injection, comes from a pipe passing through the ship's side, as low down as possible; in some vessels, it comes through the bottom, but this is not recommended; should the vessel take the ground, the pipe is more likely to receive injury, and to get choked with mud, sand, &c. a rose is

always secured on the outer aperture of the pipe.

A large cock, called a sea cock, closes this pipe when in harbour, or when the injection is not required.

Where the injection pipe enters the condenser is another cock, communicating with a leverage and a handle to some convenient place, so that, although when the engine is at work, the injection sea cock is always open, the engineer by this handle regulates the supply for the condenser.

THE BOILER.

The boiler is the source and magazine of all our power, and on preserving it in good order, depends the efficiency of the engine; much of it being out of sight may suffer a great deal of unnecessary injury if not carefully looked after.

The chief parts of a boiler are the shell, the flues, the furnaces, and the steam chest.

Boilers are very different, according to the fancy of the maker, some being square, others circular, some making each boiler separate,

others making them dependant on each other. They are made of plates of wrought iron or copper rivetted together.

The boilers most approved of, though most expensive, are those which are entirely independant one of the other. I shall proceed to describe such a boiler, presuming that when that is the case, there are generally three or more boilers according to the size of the vessel. A very general, and much approved shape for such a boiler, is nearly cylindrical, but the sides, back and front, partially flattened. The cylindrical boilers are admitted to be the strongest, but it is not always easy to get fire surface, and steam and water spaces sufficient in boilers of the circular kind, if the vessel is at all cramped for room. And the boiler we have described is very strong, far more so than the square boiler.

The boiler will have two or three fire-places, sometimes four, according to the size of the vessel.

Each fire place has a flue, or gigantic pipe, which circulates from end to end of the boiler, making as many turns as the boiler will hold, leaving between each of its folds a water space,

which should never be less than six inches wide, so that the water is between each flue, over each, under each, and between each flue and the side of the boiler.

The flues generally communicate into one, at the first bend they take, taking care that the flue is on its return before the other comes into it, so that the flame and heated air from one enters behind the other, driving their contents on together, the flue then rises through the shell of the boiler, this part of it is called the uptake, and communicates with the common funnel, or chimney.

The flues are generally contracted just at the termination of the fire-place, by a space called the bridge, which rises up and diminishes the height of the flue one half. The space under the bridge is full of water; the bridge augments the draught. The fire-places or furnaces, are divided into two parts by the fire bars, which slope downwards at a considerable angle; on these the fire rests. Each fire-place is provided with a door, which closes the space from the mouth of the furnace to the fire bars, but the space below the fire bars, as far as the bridge, is open, and is called the ash pit; thus

all the air required for the consumption of the fuel must pass up through the fire bars. In front of each furnace is an iron bar, on which the firemen rest their fire tools, which with large furnaces, are necessarily very long and heavy.

The shell of the boiler surrounds the flues, and closes in the space in which the water and the steam is to be.

Plates of iron or copper are rivetted together by rivets driven in red hot, which on shrinking, by cooling, contract and bind the plates together with great strength; both the flues and the shell of the boiler are formed of these plates, and the edges of the plates where they overlap each other, are caulked, by hammering with a caulking chisel on the edge of the plate; after an iron boiler is complete, it is filled with water, and wherever a leak or weeping takes place, the iron, by its oxidation, fills up the crevice, and ensures the boiler being tight.

The flues are sufficiently high and wide to admit of men entering them with facility, for the purpose of sweeping out the soot, and the various deposits of burnt coal; there is gene-

rally as much space above the flue for water and steam, as there is from the top of the flue to the bottom of the boiler; the depth to which the flues are covered with water depends on the size of the boiler, but it is very important that they should never be uncovered; and there should be as much space for steam as is occupied by water.

In the separate boiler we have described, a pipe of cast iron, or other metal, goes from the upper part of the boiler into a main or common steam chest, from which is to issue the main steam pipe, and can generally be closed by a flap valve, so that one boiler or more may be thrown out of use, if desired.

Strong stay bolts, rivetted at each end, secure the flues to each other, and to the sides of the boiler; and there are strong braces in the crown of the boiler, from side to side, and from the flues to the front, top, and back of the boiler.

In front of the boiler are the various gauges, a glass water gauge, a steam gauge, and gauge cocks at various heights, to ascertain, at all times, what quantity of water may be in the boiler.

The water gauge is a glass tube, fixed at

both ends in a socket of brass or iron, penetrating into the boiler by two very small apertures, and fixed there steam tight; it is provided with two cocks below and one above; by opening the upper and lower cocks, the water will stand in the gauge exactly at the height it is in the boiler, and by opening the third, the contents of the gauge are expelled, and the glass cleaned by steam passing through, till it is quite transparent; sludge and dirt will sometimes get in and choke the glasses, the gauge cocks are therefore useful as triers of the actual water in the boilers.

A small plate of iron or copper is secured inside the boiler, against the apertures for the water gauges, to prevent, as much as possible, any dirt from choking them.

There ought to be a steam gauge on each boiler, but it is very seldom found; a mercurial gauge is liable to some objections on account of the great vibrations of the mercury; in the preliminary chapter, the principle of such a gauge has been explained.

To the boiler, at its lowest part, is attached the blow-off pipe, which passing underneath the bottom of the boiler, comes out into the

stoke-hole, and communicates with the water outside, by what is called the blow-off sea cock.

The operation of blowing off, and its necessity, will be explained further on.

In the front of the boiler, and generally below the upper part of the flue, the feed pipe is attached, the supply of water through it being regulated by a cock.

Between each flue, is a sludge hole, or hole filled up by a plug, screwed in from the outside and bottom part of the front of the boiler; when this is opened, mud, deposits of salt, &c. &c. can be raked out, and the boiler washed out, which, on all proper occasions should never be neglected; in boilers where the bottom has considerable convexity, there is room between the bottom of the flue and the shell for a man to enter, and these boilers can be much more effectually cleaned than when no such space exists.

In the crown of the boiler is a large circular opening, called a man hole, which is filled up by a stout iron plate, strongly secured with iron bars and screw bolts, this is to allow of men entering the boiler to thoroughly clean it, remove deposit, &c. &c.

The boiler just described, is one of the side, or wing-boilers, where there are three; the main or centre boiler differs in no respect from this, save in having on its crown the general magazine of steam,—the steam chest; a large space is left in the crown of the boiler, on which goes the steam chest, surrounding the funnel; and the steam pipes from the side boiler communicate into this chest; from this issues the steam pipe that supplies the cylinders; and here are the safety valves. The steam chest forms a lofty chamber, above the upper part of the main boiler, as it is a great object to get the steam as dry as possible, and not mixed up with sludge and dirt, which the ebullition of the water throws up.

On the upper part of the steam chest, in the most convenient part, is bolted a chest or box, containing the two safety valves; holes are cut in the steam chest for the valves, which are flat, of brass, with their edges ground to an angle of forty-five degrees, attached to a spindle, which passes through a collar in the cover of the box; this spindle is generally of sufficient length to admit of a number of circular weights being placed upon it, so as to prevent the safety

valve being forced up till the steam has acquired the intended strength; one of these valves generally communicates with the engine room by a series of levers, so that without going on deck the engineer can raise the valve. It is also common to see the other valve loaded altogether inside the box, so that no means can be used to increase the weight on this one, and however heavily the one may be loaded, if the other opens at the usual pressure, no mischief can be done. It is always, I think, desirable to be able to lighten the load of the safety valve when going slow, or with a fair wind, &c. &c.; and by having one valve accessible, and the other not, it is easy to do this, and prevent any possibility of overloading the valve.

Between the two valves there is a third hole, over which is bolted the waste steam pipe, so that when the valves rise they deliver the steam into this pipe, and it is carried into the atmosphere.

The waste steam pipe is generally of cast iron or copper, terminating at its upper end in a bell mouth; at this place is a disk of metal, nearly occupying the whole diameter of the

pipe, so as to prevent any sludge, &c. from issuing out at the mouth of the pipe, and falling on the decks of the vessel; a small pipe conveys any steam that may become condensed from the box containing the valves, through the ship's side overboard. Steam will often be observed issuing through this pipe, when both safety valves are raised, and abundance of steam escaping.

The steam pipe which supplies the cylinders is of cast metal, firmly secured to the steam chest; it divides into two parts, one for each cylinder, and has a valve at each extremity, close to the cylinder, called the throttle valve; by opening or shutting which steam is admitted into the valve casing; this valve has a spindle through it, is of an oval shape, and when opened presents its edge to the steam. A convenient leverage and handle is fixed to this spindle, and it is generally brought close to the valve casing, with a clamping screw to fix it open or shut as desired; by the side of this handle is the lever that regulates the quantity of water to be admitted into the condenser through the injection pipe; it also has generally a clamping screw to prevent its shifting;

a brass or copper plate, marked the one steam, the other water, points out the respective valves to which these handles belong.

The boilers will easily be filled to a level with the water's edge, by opening the blow-off cocks already described; each boiler should have its own, and if more water is required, the lift and force pump, formerly mentioned, has a pipe opening into the feed pipe, and the boilers can be filled to any height by means of it. In filling the boilers, if there is any air in them, it should be allowed to escape through the safety valve.

The description of the above set of boilers, relates to separate and independent boilers, placed side by side, and permitting each boiler to be worked by itself; but it is most usual to find boilers not so constructed; in that case, each side boiler, instead of being whole, has the side intended to be in contact with the centre boiler imperfect, and the side of the centre boiler forms the side of the other; this joint is called a smoke joint, and when the boilers are placed side by side, plates of iron are rivetted under the joint, and up the front and back of the boiler, and filled with a compo-

sition termed fire clay, which is impervious to flame, &c. &c., and prevents a leak; the flues from the wing boilers communicate into the flues from the centre, and after making a turn round the wing boiler, do the same in the centre boiler, and rise into the chimney. A steam chest rises out of the crown of the centre boiler, and the steam flows into the chest from the wing boilers through holes cut in the side walls of the centre boilers; each boiler having its feed pipe, gauges, and blow-off pipes as before, and the water in each boiler having no communication with the other, unless from very violent rolling, sending the water through the holes cut for the steam.

These boilers are strengthened the same way as the others, by stay bolts and braces, and this sort of smoke joint is considered perfectly safe; the only risk is where the flues pass from one boiler into the other; it is just possible that a leak may take place at this point of the flue, without letting out the water, which is over the flue in each adjacent boiler; but even then, if flame were issuing, the iron plates and fire clay we mentioned, would prevent damage, unless the clay should have crumbled out, &c.

There is a possibility of danger in this sort of boiler which does not exist in the separate boiler; and in spite of the increased expense, for vessels of war, the separate boiler is the only one that ought to be used.

I shall not say much about rectangular boilers, and boilers divided into after boilers and fore boilers; but I refer the reader, who may be curious, to Mr. Dinnen's paper, in the appendix to Tredgold's work, and I am sure he will receive the greatest benefit and instruction from its perusal.

Both in Scotland and in Liverpool many boiler makers are making them with two ranges of furnaces, one above the other, with a water space between; the flues being so arranged, that the dense smoke and unconsumed particles of fuel from one, pass the flame and greatest heat of the other on their way to the chimney, and thus, in a great measure, all the smoke is consumed, and fuel saved, while a greater extent of fire surface is gained in the same space; of course the more fire surface gained, the greater the power of generating steam; the objection urged against them is the difficulty of cleaning the boiler, and that

the operation of blowing out is less efficient; but the using fresh water, by the application of Hall's condensers, would remove the chief part of this inconvenience.

The chimney, or funnel, is made of sheet iron, and rivetted on to the uptake, it is surrounded by an air casing of sheet iron, where it passes through the deck; this is a necessary precaution, as the intense heat of the lower part of the chimney might set fire to the deck.

Boilers are liable to decay in the lower part of the shell; where in contact with the sleepers, all copper bolts should be driven well below the upper surface of the sleeper, and the space above them filled in, and the sleepers themselves well coated with red lead; it is of importance that no bilge water should come in contact with the lower part of the shell of the boilers.

To each boiler, when it is independent of the other, should be attached a separate damper, to cut off the communication from the common chimney; the damper is usually placed in that part of the uptake which passes through the steam chest, besides which a large common damper should be fitted to the main chimney near the deck.

A damper is a circle or disk of metal, which can be turned edge up in the passage, it is fitted in, or with its flat surface up or down, closing or opening the passage at pleasure; its use is to regulate the draught; a small handle comes through the chimney, and a bolt falls into a toothed wheel round the spindle of the disk to secure it to the desired position.

Figure 1, plate 3, is a ground plan of a separate set of boilers; *A*, the centre boiler; *B B*, the two wing boilers.

a a, are the fire-places; *c*, is the bridge, though in some boilers fire bricks are used here, as the plates which form the rising of the bridge are exposed to the fierce blast of the whole heat of the fire; but I think the best engine makers are opposed to their use; the space under the bridge where it exists, is always filled with water.

b b, are the flues, circulating the flame and heated air through the boiler terminating at *d*, called the uptake.

c c, are the water spaces, between each turn of the flue at the sides of the boiler; besides which the flues are covered to a certain depth

with water, the quantity depending on the size of the boiler.

The spaces *c c c*, between the fires, are also full of water, the arrows represent the course of the flame and hot air through the flues *b b b b*.

Figure 3, plate 3, is a transverse section of the same boilers at *C D*, the spaces *b b b*, are the flues, the shaded space represents the water.

d d d, the uptake, communicating from each boiler, in the common funnel or chimney *E*.

f f, is the steam chest; the wing boilers *B B*, communicate into the steam chest by a pipe from the front part of the crown of the boilers; *e e*, not shewn in this view.

g g, is the air casing, surrounding the chimney *E*; *h*, is the damper.

PART III.

HAVING in the preceding chapter given a description of the working parts of an engine, as commonly used on board vessels intended for sea navigation, I shall proceed to describe the starting and working of one of this kind, and I think the general remarks which I shall offer will be found applicable to all marine engines, however differently they may be constructed.

1st. It may be remembered that the boilers can be filled up to the level of the water outside the ship by opening the blow-off cocks, and if any more water should be required, a pump is had recourse to. If the weights are moveable on the safety valve, it is recommended to get the steam up, with the greater portion of

the weights taken off, but if the weights cannot be got at, when the ebullition commences, the safety valve should be raised by hand.

It is to be remembered that the boiler, in most cases, contains a quantity of air, that the boiling of the water rarefies and expands that air, and that if not got rid of through the safety valve, it will have to pass through the blow-through, or tail valve, whereby much time would be lost.

It is essential to the due working and readiness of the engine, that prior to starting the vessel, the paddle wheels should perform a turn or two, that all air, water, &c. should be expelled from the condenser, and especially that by no chance any water should remain in the cylinder.

It has been already observed, in describing the cylinder, that owing to the incompressible nature of water, if the piston should come in contact with it at either end of the cylinder, and there be no escape for it, something must break, a sway beam, a side rod, or a piston itself; for it is to be remembered, that at the moment of one piston being at either end of its stroke, and its crank therefore vertical and with no power, the piston of the other engine

to which it is coupled, is at half stroke, and its crank, therefore, at right angles to the other, exerting, at the moment, its maximum power; the engine, therefore, whose crank is vertical, is forced to the extremity of its stroke by the whole power of the other engine, and if an incompressible space of water exists between the surface of the piston and the end of the cylinder, either at top or bottom, something must break; in such cases it is generally a sway beam. Most cylinders are provided with two escape valves for this purpose, one through the bottom of the cylinder, the other in the cylinder cover, but they are not to be found in all engines, and are often so small as to be of little use, except as a warning to the engineer; where they are used, they are loaded with a weight on each square inch of their surface, exceeding that of the safety valve.

It is on this account, that on starting the engine, it is absolutely necessary to work three or four strokes by hand prior to throwing the eccentric rod in gear, and allowing the engine to work herself.

As was explained in describing the setting of

the slide valve, both ports are closed at once, and the port towards which the piston is moving, will not open till the very end of the stroke, till the piston is within three-quarters of an inch of either end of the cylinder; now if two inches of water in this case existed between either end of the cylinder and the piston, something must break, for the power of the other engine is at the moment infinite, and water cannot be compressed; but if the eccentric be not in gear, and the engine working by hand, the port towards which the piston is moving is left open, any water can then escape into the condenser, and the port is not shut or steam admitted to the other end of the piston till the engine has turned its centre by the power of the other engine, and has acquired its greatest power at the moment the other arrives at the critical point; if this operation be done once or twice carefully, the eccentric may be thrown into gear, and the engine will then work itself.

Prior to doing this, the engine must be blown through, the air and water expelled through the tail valve from the condenser, and

the whole filled with steam, ready, on the admission of water through the injection pipe, to form a vacuum.

The snifting, or blow-through valve, admits steam from the valve casing into the condenser, as formerly described, and the steam filling the condenser expels, by its pressure, water and air through the tail valve at the foot of the air pump.

It will always be right to blow through after stopping the engine for any time, as well as on starting.

It may also happen, that in a small vessel, where the force due to the head of water through the injection pipe is not very great, the condenser may become so hot that the pressure of steam prevents the water from entering, and no vacuum can be formed, besides expelling scalding steam through the tail valve; in such case the steam must be shut off, the safety valve raised, and the condenser cooled by pouring or pumping on it plenty of cold water, till the condensation is effected from outside.

This heating of the condenser will also take place from the leaking of the slide valve in the

way of the packing, in which case the same effects might ensue.

The former case is not likely to happen in a large vessel, for the depth of the vessel ensures to the injection water sufficient power to overcome any ordinary pressure of steam.

Also it may happen, that from the position of the engine, the water in the condenser being above the snifting valve, cannot free itself through the tail valve ; in this case a stroke of the other engine, by lifting the air pump enables the blowing through to be completed.

After being blown through, and a turn or two taken by hand, the engine is ready for starting ; but if any time elapses before a move is made, she must be again blown through.

It is also necessary, or at least advisable, to place the engine with its crank somewhat nearly at right angles to the horizon, or to speak more correctly, one having turned its centre descending, and the other, passed the right angle ascending, when both cross heads will be up. The reason of this is, that it is much more unlikely that water will be above the piston, than below it; so that giving the

descending piston the steam, brings the ascending one over its centre, (the port being open for the escape of water,) and then giving the second piston steam, and opening the port for the first, it is carried over its centre, and the water driven into the condenser.

But if the cross heads were both down, one piston past its centre and ascending, and the other past the right angle descending; the motion to be given the descending piston, to enable it to turn its centre, must come from the ascending piston, and should there be water in that cylinder, the steam coming in contact with it is condensed, and a vacuum formed; when the piston will descend instead of ascending, some time will elapse before the steam will heat the water sufficiently to prevent its condensing.

The blowing through having been performed, and the engine put carefully over its centres once or twice, or oftener, (for it is best to be sure,) the eccentric may be put into gear, the engine will work itself; if desired to stop or slow, shut at once the throttle valve and injection water, if *slow* only, turn on as much injection and steam, as is sufficient to keep the

engine just moving, bearing in mind, that a very small opening of the throttle valve will admit nearly as much steam as a large opening, and that the degree of vacuum, or the strongest portion of the moving power in a low pressure engine, is influenced chiefly by the injection water.

It is very common to find no gauge on the condenser; some are even without a cock, to which a temporary one might be affixed; the engineer feels the temperature of the condenser, and judges by that of the vacuum, &c.; this is the rule of thumb with a vengeance.

The engine should always, except in case of absolute necessity, be *slowed* or eased, before it is stopped. When intending to stop, the throttle valve and injection being shut off, the engineer watches the eccentric rod, closing the ports, immediately throws it out of gear, ships the starting bar ready for a back turn. If the wheels have great velocity at the moment of stopping, they will perhaps revolve a turn or two from their momentum, compressing the steam in the cylinder, and incurring much risk to the machinery.

When it is desired to back the engine after

stopping, the steam is admitted by hand, the reverse way; the shaft in revolving in the opposite direction disengages the catch on the pulley for the direct motion, and engages with the reverse, the slide then works by the eccentric as before, but with a reverse motion.

Care is always to be taken on stopping to shut the injection cock entirely, and on slowing to diminish the quantity of water admitted in proportion to the diminished action of the air pump.

The engine being fairly at work, it will be as well to recapitulate what it actually does.

The fires turn a certain quantity of water into vapour, the elastic force of this vapour conducted into the cylinder, forces the piston up and down alternately, (not being resisted by any pressure on the other side of the piston;) the piston by its cross head and side rods, work the sway beam, the sway beam works the connecting rod, the connecting rods force the cranks round, and the cranks turn the shafts and wheels; the shaft in revolving, lifts the slide up and down, and admits the steam above and below the piston; besides which, the sway beam works the air, feed, and bilge pumps; as

the steam is constantly being expended at each stroke, the water would fall lower and lower in the boiler, if not replaced by the feed; the feed pump forces a portion of the water from the hot well into the boiler; consequently, less fuel is required to make this water boil, than if it were introduced cold. The general temperature of the water in the hot well, is from 100° to 120°,; at this temperature steam has an elastic force, represented by 3·3 inches of Mercury, the vacuum indicated by a barometer gauge would be between 26 and 27in. in some very well made engines, the vacuum indicated is as high as 29, and 29·5, (vide two of Wilberforce's engine diagrams in Tredgold,) but this excellent vacuum is to be attained much easier with low pressure steam than with strong steam.

It is evident that as at each successive stroke of the engine a certain portion of vapour is condensed, the water in the boiler must gradually increase in saltness, for no salt is taken away with the steam; it all remains in the boiler, which would soon become saturated with salt, and finally fill up altogether with it.

Great injury is done to a boiler by the increasing saltness of the water, for while common sea water, under the ordinary atmospheric pressure, will boil at 213° of Fahrenheit, at which time it contains $\frac{1}{33}$rd of its weight of salt, when it contains $\frac{5}{33}$rds of its weight of salt, it will not boil under similar circumstances till it has reached the temperature of 218°, and when it contains $\frac{12}{33}$rds of salt, it will not boil till its temperature is 226°, shewing the great increase of firing required, to the certain injury of the boiler. It is therefore indispensable that the water in the boiler should be kept at a certain degree of saltness, as low as possible, from this cause alone; but there is another still more urgent reason for not allowing the water to acquire the last named degree of saltness.

Up to a certain point of saltness, the salt is held in solution in the water, after this point, or when the water contains $\frac{12}{33}$rds of its weight of salt, it can contain no more, it deposits its salt on the sides, flues, and bottom of the boiler; now though plates of iron will stand any degree of heat when in actual contact with the water, yet if any intervening non-conducting

substance be between the plate and the water, a small quantity of heat suffices to destroy it, and this deposit is just such a substance; while by its non-conducting properties, the water is more slowly heated, and therefore the fires require to be more urged; the plates themselves from not being in contact with the water, are rapidly and easily destroyed. It is therefore absolutely necessary to maintain the water at a certain degree of saltness.

The common method of doing this, is by letting a rather larger feed on for some time than the boiler actually requires, and then opening the blow-off cock, and letting a certain portion of the boiling salt water out to be filled up with ordinary salt water; care is necessary in blowing off, that too much water be not allowed to run off, as, of all the causes of accidents, none are of such frequent occurrence as the want of water in the boiler; in blowing off, therefore, the gauge cocks should be frequently tested, and the glass gauge cleaned and proved before the operation is begun.

A brine pump has been invented by Messrs. Maudslay and Field, and is applied to some of their engines; I believe to the Great Western

amongst others. Its principle is to extract by means of a pump a certain quantity of the saltest water in the boiler; the quantity so taken from the bottom of the boilers being one-fifth of that supplied for feed (vide Dinnen's Observations on Boilers, Appendix to Tredgold). This seems a sure, certain, and definite remedy, which blowing off is certainly not.

The intervals between blowing off, the quantity of water blown off will depend upon the size of the boiler, pressure, &c., &c., and can be regulated only by bearing in mind that the water shall not exceed a fixed degree of saltness, say $\frac{5}{33}$rds of salt; this can be ascertained every half hour by boiling a small quantity of water drawn from the boilers in the engine room, and noting its temperature by a thermometer; for, as we said before, the temperature at which water boils under the ordinary atmospheric pressure is an infallible test of its saltness.

In very muddy water, even if it is fresh, as the deposits of mud act on the bottom, sides, &c., of the boilers, as non-conducting substances, blowing off should be resorted to.

It cannot be too often repeated, that on the

careful, judicious management of the boiler, all the efficiency of the engine depends; that as all great things are but the sum of a number of small ones, no care, no precaution ought to be considered too minute; and that with this important part of the engine we cannot be too particular.

On the vessel's anchoring, and the steam being no longer required, the fires are drawn and extinguished, and the water in the boilers driven violently out of the blow off pipes by the expansive force of the steam; any deposits that are loose, are driven out by this blowing off.

As the boilers become cool after the operation of blowing off, the steam in them condenses, and would form a vacuum in them; few boilers are of sufficient strength to resist the external pressure of the atmosphere, and air must therefore be let into them as they cool, to prevent the crushing together of their parts by the atmospheric pressure. Air may be let in through the safety valve, or by a gauge cock; and I have observed, that all engineers dislike admitting air in any quantity into the boilers, as they say it hardens the

saline and earthy deposits; of course, if the boiler has to be cleaned out, which should be done whenever there is time enough for it, the man hole door is taken off, and plenty of air necessarily admitted.

An air valve, or reverse valve, is attached to some boilers, which yields to external pressure only, being forced against the interior of the boiler by a spring, which will yield to a certain amount of pressure, considerably less than would be sufficient to injure the boiler; they are not generally used in marine boilers made in the north of England, or Scotland. Those boilers are never square, and as they are generally calculated to work with a pressure exceeding that of the atmosphere from eight to ten pounds, there is less necessity for using that precaution.

The parts of iron boilers most likely to decay, when proper attention is paid to the interior, are the lower parts of the shell, in situations where they cannot be seen, or got at; wherever, from any cause, salt water gets at them, and is alternately wetting the shell and then leaving the salt to form incrustation, &c.; leaks from the deck round the

steam chest have a very prejudicial effect on that part of the shell; the bilge water below is still more destructive.

Considerable mischief is also done by unavoidably wetting the ashes in the stoke-hole, the lower part of the front of the boilers being on a level with it, is much injured by the salt water, and the less used there the better; the decay in iron boilers from wetting the ashes in the ash pit, is very serious; and, as much as possible, all water should be kept away from the exterior of the boiler.

The water from the gauge cocks, in many engines I have seen, is allowed to run on the flooring of the stoke-hole; this, a cause of mischief easily prevented, by letting the gauge cocks discharge into a pipe conducted into the bottom of the vessel.

All boilers, as a matter of absolute necessity, should be furnished with a steam gauge; this is not always done; engine makers trust to the safety valve, which may become gagged or rusted, and incapable of motion. If accurate gauges of considerable size were attached to all boilers, a barometer gauge to the condenser, and then careful observations made with the

indicator, positive results could be obtained from certain premises; different constructions would shew their advantages or defects at a glance, and a succession of facts be established which would enable us to have certainty on points which are involved in doubt at present.

A word or two should be said on the subject of Hall's condensers. I hope it will not be considered presumptuous in me to say, that this invention of Mr. Samuel Hall is *the great* improvement we have made in the steam engine since it was adapted to marine purposes. The invention, for which that gentleman has a patent, consists in using distilled water to supply the boilers, instead of feeding from salt water, and in condensing the steam by contact with cold water surrounding a number of small tubes, and returning this condensed steam to the boilers; so by filling the boilers with fresh water originally, a constant succession of distilled water is procured, and all the injury done to boilers by saline deposits is at once removed. Mr. Hall has provided a most ingenious apparatus, which, by distilling salt water, replaces any waste of the original requisite quantity, and

which also regulates itself. A vessel of copper, or other metal, introduced into the boiler, is filled with salt water (from the outside of the ship) to a certain height; the heat of the water in the boilers causes steam to be formed in this vessel, which communicates with the condenser by a pipe, and flows into it as there is a vacuum, where it returns to water; he has also an apparatus by which all the steam from the waste pipe is saved, and he heats the water which feeds the boiler before it is admitted into it, so as to save fuel.

The vacuum obtained by contact with the cold surfaces of the pipes above mentioned, has been repeatedly proved to be equal, if not superior, to that caused by the common plan of injection. As many persons conversant with steam have doubted the fact, I will quote the performances of an engine belonging to the Wilberforce, London and Hull steamer, shewing in different circumstances a most extraordinarily good vacuum; the Wilberforce was fitted with Hall's condensers.

April 7th, 1838, pressure of steam in the boilers 5lbs., condenser gauge 29·5, at 2h. 30m. p.m.

April 7th, at 11h. 30m. p.m., wind N.W., heavy swell, pressure of steam in the boiler 6½lbs,, condenser gauge 29·5 inches.

April 12th, 10h. 30m. a.m., pressure of steam in boilers 6lbs., condenser gauge 29·5 inches.

It is scarcely possible that a better vacuum could exist.

Mr. Hall points out various other advantages attendant on his plan; one of which, the more perfect bearing of all the parts in contact, from no salt being mechanically admitted with the steam into the cylinders, &c., and that while the oil, &c., put into the cylinders, stuffing boxes, &c., is rapidly carried away through the waste water pipe into the sea, in the common injection engines, in his, it is returned by the air pump to the boilers, and thence again mechanically diffused over the engine, to its manifest advantage.

These condensers are coming daily into use, though being more expensive than the common injection engine at first, they have not been so universally adopted as their undoubted merit deserves. The British Queen is now fitting at Glasgow with them, and on this large scale, and, in connexion with Atlantic steam naviga-

tion, their merits cannot fail of being brought conspicuously to light.

In connexion with the subject of boilers, it would be most desirable if at all times the temperature of the water in the boilers could be ascertained by inspection; a thermometer might be affixed to the front of the boilers, the bulb immersed in mercury, contained in an iron box standing in the water; this thermometer should be graduated from 212° to 250°, and on inspection would shew at once the state of the water in the boiler; the load on the safety valve being known, the boiling point would be marked accordingly; any variation in excess of this temperature would warn the engineer of the increasing saltness of the water, and of the necessity of blowing off, &c. &c.; in short, if a thermometer of this kind were fixed to each boiler, duly registered every hour, and the result attended to, we should never hear of a boiler being ruined on the first passage to the Mediterranean.

But it is in every one's power to ascertain the quality of the water in the boilers, even if no thermometer is fixed in front of the boiler, by boiling a portion of it in the open air, or,

rather, exposed to the atmospheric pressure; by doing this repeatedly, and noting the difference of temperatures at the different intervals, the exact time that ought to elapse before the boiler is blown off, and the quantity to be let out, will be correctly ascertained.

A certain portion of tallow is usually thrown into the boilers, and is useful in preventing violent ebullition, and the consequent mixing up of water with steam.

There are various opinions as to the comparative advantages of copper and iron boilers; they will be found stated in Mr. Dinnen's Appendix to Tredgold's work, which contains valuable information on the practical management of boilers.

I shall now proceed to give a few rules for ascertaining the power of an engine, which, however, is estimated differently by different engine makers, so that the nominal power of an engine, manufactured by Bolton and Watt, will not give the comparative power of the same nominal power by another engine maker. The power of an engine is estimated by the pressure exerted by the steam on one side of

the surface, minus the resistance on the other, multiplied by the velocity of the piston in feet per minute, and divided by 33,000.

We have then to find the pressure on the surface of the piston, minus the resistance on the other, and the velocity of the piston in feet per minute, the pressure of steam in the boilers is shewn by the steam gauge, so much per square inch, and the degree of vacuum in the condenser being the difference between the resistance offered by the atmospheric pressure and that actually in the condenser, shews the resistance offered to the other surface of the piston; the difference of these two will be the pressure per square inch on the piston's surface, multiply this by the area of the piston, and you will have the whole amount of the power to effect motion exerted on the piston.

But from this power deductions must be made :—

1st, by the force, producing the motion of the steam into the cylinder.

2dly, by the cooling of the cylinder, steam pipes, &c.

3rdly, by the friction of the piston and axes.

4thly, by the force necessary to expel the steam through the passages.

5thly, by the force required to open and close the valves, &c.

6thly, by the steam being cut off before the end of the stroke, and by the power required to work the air pump: these deductions amount to 368 parts of a thousand, and thus to find the mean effective pressure on the piston, we must multiply the actual pressure by ·632, which will give the mean pressure; call this *a*, and the area of the piston *b*.

To find the velocity of the piston in feet per minute, multiply double the length of stroke by the number of strokes made in a minute, call this *c*.

then $\frac{a \times b \times c}{33{,}000}$ = the horse-power of the engine.

Supposing the engine does not work expansively.

Example.

Let the diameter of a piston be 63 inches, the length of stroke 5 feet 9 inches, the

number of strokes per minute 20; the pressure of steam in the boiler $5\frac{1}{2}$lbs. per square inch, the vacuum in the condenser = to $13\frac{1}{4}$lbs.

Twice the length of stroke, 5 ft. 9 in. = 11 feet 6 in. × 20 = 230, the velocity of the piston in feet per minute.

Then to find the mean effective pressure on the surface of the piston.

$5\frac{1}{2} + 13\frac{1}{4} = 18\frac{3}{4}$lbs. on each square inch.

then,

$18\frac{3}{4} \times \left(\underset{\text{area of piston}}{3117}\right) = 59{,}441$lbs. total pressure on piston per square inch.

59,441lbs. × ·632 = 37565lbs. effective pressure on the piston.

37565 × 230, the velocity of the piston per minute in feet $= \frac{8639720}{33{,}000} = 261$ the horse power of the engine.

A most useful instrument, called an indicator, can be attached to the cylinder, which will point out the exact working state of the engine, how much of the steam is lost between the boiler and cylinder, and whether any

difference exists between the vacuum in the condenser and cylinder.

A small very portable instrument of this kind is made by Mr. Macknaught, of Glasgow, and no person who wishes to ascertain what his engine really is doing should be without one.

The indicator consists of a small brass cylinder, in which works a piston, the motion of the piston is resisted by a spring calculated to move a tenth of an inch for each pound of pressure; the piston rod carries an index, and the front of the cylinder is graduated to 15lbs. each way (for a low pressure engine).

The end of the cylinder terminates in a brass tube, which will fit into the grease cock of the cylinder cover, and this tube is opened or closed at pleasure by a small cock.

Attached to this cylinder is another small one, which is grooved round its edges so as to receive a piece of drawing paper, or card, a spring allows the cylinder to turn on its axis, so far as to keep the ends of the paper from coming in contact with the pencil, which is fixed to the rod of the piston, and accordingly carried by it up and down; to the lower part of the cylinder carrying the paper, a line is

attached, which is made fast to some convenient moving part of the engine, generally a radius bar, sufficiently close to the side rod to cause the vertical motion of the bar to turn the cylinder nearly round *once* in the stroke.

The instrument is then fixed in the grease cock of the cylinder, the line adjusted with care, so that the cylinder on which the paper is fixed revolves, without bringing the ends of the paper in contact with the pencil.

The pencil is carried by the piston rod, and has a joint by which it can be turned back from the paper, or upon it so as to mark it; the line being attached to the right point, the pencil is turned upon the paper, and makes by the revolution of the cylinder a horizontal line on the card.

The grease cock, and the cock in the indicator being opened, the instrument is in direct connexion with the cylinder. When the steam is above the piston, it will force up the piston of the indicator, and shew by the graduated scale the pressure on the piston, when the steam is below the piston; the vacuum above it causes the pressure of the atmosphere to press down the piston of the indicator, with a

force equal to the vacuum, and pointed out by the index. The piston of the indicator moves thus alternately up and down, and carrying the pencil with it describes a figure which points out the exact force of the steam and vacuum at each portion of the stroke.

Figure 5, is a diagram taken by an indicator, on board the Commodore, January 2, 1839.

The engine was made by Mr. R. Napier, of Glasgow.

The pressure of steam in the boiler was 7lbs. per square inch, and the vacuum in the condenser was 13¼lbs.

The horizontal line *A B*, in the figure is that drawn by the pencil before the cocks have opened the communication between the cylinder and the indicator, it represents the length of stroke, and by dividing it into any number of equal parts, we can trace the exact force of the steam, and the goodness of the vacuum at every portion of the stroke; for instance, let the length of stroke be 5 feet 9 inches, and say that we divide the card into ten equal parts, each division represents 6 inches

and 9 tenths of an inch; then by tracing the figure from right to left we see that the force of the steam was 6lbs. during the first 7 inches of the piston's stroke, and that it continued at that strength till the piston had gone about 42 inches; the diagram points out that the steam port was now closed, and that the expansive force of the steam already in the cylinder was allowed to complete the stroke; and we observe that at the end of the stroke, the force of the steam was rather less than the atmospheric force.

Following now the figure from left to right below the horizontal line, we see that in the first seven inches of the piston's motion, the vacuum is equal to 10lbs.; that in the next it has increased to 11¼lbs., and that its maximum is 13½lbs. We may observe, that the piston travels some way before the condensation is perfected, while the steam attains its greatest effect almost immediately; this clearly shews the necessity of having very considerable openings for eduction, and that smaller ones suffice for induction. We also see that at the termination of the stroke, the vacuum is less

perfect; and that the closing of the port before the end of the stroke has an unfavourable effect on it to a slight extent.

This diagram is, however, a very good one; of course, the nearer to a parallelogram the figure made by the indicator approaches, the more uniformly and constantly the forces are acting, and the better the engine is working. In this instance, the mean effect of the forces is, for steam 4·52lbs., and for vacuum 11·8lbs. —total 16·32lbs.; the total of the force in the boiler and condenser being 20¾lbs., and the maximum force exerted in the cylinder being 19½lbs. I have seen but few diagrams of engines where the loss between the maximum force in the cylinder and the maximum in the boiler and condenser was so little as this Of course, the difference in the mean effect will depend very much on what period of the stroke it is determined to cut the steam off, and, it may be observed, that the great cover given to the valve, while it operates to the saving of steam and fuel, and advantageously in condensing rapidly at the moment of contact with the cold water, operates rather to

the injury of the vacuum at the close of the stroke, from closing the port too soon.

If we compare this diagram with the one given in Tredgold's work, as taken on-board the Wilberforce, fitted with Hall's condensers, the following will be the result. The total force in the boiler and condenser, in the Wilberforce, was 19¾lbs. per square inch, and the mean effect was 15·35lbs., the maximum force in the cylinder being 17lbs. per square inch; now, the mean force in each case is proportional to the maximum force in the boiler and condenser; but the maximum force in the cylinder of the Commodore exceeds the proportion of the maximum force in the cylinder of the Wilberforee; in other words, less force is lost in the passages, cooling, &c.; and if the Commodore's steam were not cut off so soon as it is by the action of the long slide, the mean effect would be greater proportionally than the mean effect of the Wilberforce's engine.

The indicator, by giving us the mean effective force on the surface of the piston, enables us most readily to calculate the horse power of the engine, viz., the mean force found by the

diagram must be diminished by 2lbs. per square inch, which is considered the quantity lost in working the air-pump, and by friction, &c.; then with this force as mean effective pressure, multiply the area of the piston by it, and the product by the velocity of the piston in feet per minute, divide this product by 33,000, and the quotient will be the horse power.

EXAMPLE.

Mean effective pressure 16·32 — 2 = 14·32 log.	1.155943
Area of piston (64 inch cylinder) 3217	3·507451
Velocity of ditto 190 . . .	2·278754
	6·942148
33,000 divisor	4.519171
	2·422977

Horse power = 264·8.

Very little power is lost by working the steam expansively: for instance, the Commodore, under the same circumstances, cut off

her steam at half stroke by the use of the slide formerly described; the velocity of the piston was reduced from 190 feet per minute to 184; the mean pressure shewn by the indicator for steam was 3·67, for vacuum 11·77, total 15·44; diminishing this by 2, we have, therefore, as the mean effective pressure, $\frac{13 \cdot 44 \times 3217 \times 184}{33,000}$ $= 241$ horse power. Thus while half the quantity of steam is saved, the loss of power by the engine is less than an eighth. In both cases, the engine was working considerably above its nominal power.

I shall now give a few rules for calculating the force and volume of steam, taken from Tredgold, and which will obviate the necessity of having recourse to the tables in that expensive work.

To find the elastic force of steam when in contact with the liquid from which it is formed, the temperature being given.

RULE.

Add 100° to the temperature indicated by Fahrenheit's thermometer, and from the logarithm of this sum subtract the logarithm from the table below due to the degree of the salt-

ness of the water, multiply the remainder by 6, and the product will be the logarithm of the force in inches of mercury.

Proportions of salt in 100 pints by weight.		Boiling point.	Constant number.*	Constant Log.
Fresh water	0	212·	177·	2·24797
Sea water	3·03	213·2	177·6	2·24950
Boiler water	$\frac{2}{33}$	214·4	178·3	2·25130
"	$\frac{3}{33}$	215·5	179·	2·25281
"	$\frac{4}{33}$	216·7	179·7	2·25446
"	$\frac{5}{33}$	217·9	180·4	2·25610
"	$\frac{6}{33}$	219·	181·	2·25760
"	$\frac{7}{33}$	220·2	181·6	2·25923
"	[illegible]/33	2·214	182·3	2·26086
"	$\frac{9}{33}$	222·5	183·	2·26234
"	$\frac{10}{33}$	223·7	183·6	2·26396
"	$\frac{11}{33}$	224·9	184·3	2·26556
Saturated solution	$\frac{12}{33}$	226·	185·	2·26703

From this table, and from what was observed on the boiling point of salt water, fur-

* The constant number is to be used when tables of logarithms cannot be got at; in which case, for subtract, read divide by the constant number, and raise the quotient to the 6th power, &c., &c.

ther back, it is plain how much the elastic force of steam from salt water is less than that of steam from fresh water at the same temperature.

To find the elastic force of steam from any boiler containing salt water, we must first ascertain the degree of saltness in the water, by boiling it exposed to atmospheric pressure, and then proceed as by the rule, taking for the constant logarithm the number due to the boiling point of the water.

EXAMPLE.

Suppose the temperature of the water to be 250° of Fahrenheit, and the water to be fresh

Temperature	250	
Add .	. 100	
	350 log. .	2·54407
In the table for fresh water, the constant log· is		2·24797
	Difference .	0·29610
	Multiply by	6
	Log. 59·8 .	1·77660, the elas-

tic force is 59·8 in. Mercury; but suppose by boiling the water we have ascertained that its

boiling point is 217·9, and that it therefore contains $\frac{5}{33}$ of its weight of salt, we must proceed as follows:—

Temperature	250	
Add . .	100	
	350 log. .	2·54407
Constant log. from the table, due to water, containing $\frac{5}{33}$ of salt .		2·25610
	Difference .	0·28797
	Multiply by .	6
	Log. 53·4 .	1·72782

The elastic force is in this case only 53·4 in of mercury instead of 59·8; and every 2 in. of mercury represent a force of nearly 1lb.; of course, in the case of saturated water, the difference is still greater.

RULE II.

To find the volume or space the steam of a cubic foot of water occupies when the steam is of a given elastic force and temperature, and separated from the liquid from which it is generated.

To the temperature in degrees, add 459, multiply the sum by 38, divide the product by the pressure in pounds per square inch.

EXAMPLE.

```
        Temperature 250
        Add   .   . 459
                    ---
                    709
        Multiply by  38
                    ---
                   5672
                  2127
                  -----
Elastic force 59·8)26942(450
                  2392
                  ----
                   3022
                   2990
                   ----
                   ··32
                   ----
```

450 cubic feet nearly, if the water were fresh; but considering the water to contain $\frac{5}{33}$ of its weight of salt, as in the former example, the divisor would be 53·4, and the space occupied would be 500 cubic feet nearly.

To find the number of cubic feet in the volume of a given cylinder.

Multiply the square of the diameter in inches by half the length in inches, then cutting off two figures from the right hand, divide the product by 11; the result will express the required volume in cubic feet.

EXAMPLE.

What is the volume of a cylinder whose diameter is 36 inches, and length 32?

$36^2 \times 16 = 20736$, cutting off the two last figures on the right, and dividing by 11, $\frac{207\cdot}{11}$ $= 18\cdot85$ cubic feet.

To find the quantity of water required for steam, find the volume of steam from a cubic foot of water by Rule 2nd.

Multiply the square of the diameter of the cylinder in inches by half the velocity of the piston in inches, or six times the velocity in feet per minute, cut off two figures from the right hand, divide by 11, and the quotient will express the cubic feet of steam effectively expended per minute, divide this by the volume

from a cubic foot of water, and we get the cubic feet of water required per minute.

EXAMPLE.

Let the diameter of a cylinder be 64 inches, the velocity of the piston 190 feet per minute, and the volume of steam from a cubic foot of water be 1049.

$$64^2 = 4096 \times \left(\frac{190 \times 6}{1140}\right) = \frac{46694\ 40}{11} = 4245$$

cubic feet of steam effectively expended per minute, which, divided by 1049, gives 4 cubic feet of water nearly, as the quantity required per minute.

To this, something should be added for waste, leakage, &c., &c.

About 12 times the quantity is required for injection.

To find the mean pressure of the steam on the piston when it is worked expansively.

Divide the length of the stroke by the distance the piston moves before the steam is shut off, and the quotient will express the relative expansion it undergoes. With this number, take out the multiplier from the table below, and multiply it into the full pressure per

square inch of the steam on entering the cylinder, the product will be the mean pressure per square inch.

Multiplier for mean pressure of steam worked expansively.

Relative expansion.	Multiplier.	Relative expansion.	Multiplier.
1·100	0·9957	3·100	·6875
1·200	·9853	3·200	·6760
1·300	·9710	3·300	·6648
1·400	·9546	3·400	·6540
1·500	·9370	3·500	·6436
1·600	·9188	3·600	·6336
1·700	·9004	3·700	6239
1·800	·8821	3·800	·6145
1·900	·8641	3·900	·6054
2·000	·8466	4·000	·5966
2·100	·8295	4·100	·5880
2·200	·8129	4·200	·5798
2·300	·7969	4·300	·5718
2·400	·7814	4·400	·5640
2·500	·7665	4.500	·5564
2·600	·7521	4·600	·5491
2·700	·7382	4·700	·5420
2·800	·7249	4·800	·5351
2 900	·7120	4·900	5284
3·000	·6995	5·000	·5219

EXAMPLE.

Let the length of stroke be 69 inches, and let the piston travel 34·5 inches before the steam is cut off.

then $\frac{69}{34 \cdot 5} = 2$; the multiplier for 2 is 0·8466 the full pressure on entering the cylinder was 19·5lbs.; 19·5 × 0 8466 = 16·5lbs. mean pressure

This quantity is slightly in excess of the mean power, shewn by an indicator attached to this cylinder, when the steam was cut off at half stroke, the mean shewn by the indicator, being 15·44.

To find the throw of the eccentric, the length of the levers being given.

Rule, multiply the length of stroke of the valve, by the length of the lever on the weigh shaft, for the eccentric rod, and divide the product by the length of the lever which works the valve, and the quotient will be the throw required.

To find the temperature of steam, its elastic force being given in inches of mercury, divide the logarithm of the force in inches of mercury

by 6, to this add the constant logarithm, corresponding to the degree of saltness of the water, the sum is the logarithm of a number, from which, 100 being subtracted, will give the required temperature.

Mr. Tredgold gives as a rule, that there should be 62 times as much water in a boiler, as is introduced at one feed, and that if the boiler be fed at each stroke, it should have five cubic feet of water for each cubic foot of steam it is capable of boiling off per hour, whether the boiler be high or low pressure.

He also says that there should be from 25 to 20 cubic feet of boiler, for each horse power, but engine makers are not agreed as to the proportion requisite.

As a general rule for low pressure engines, it may be concluded, that for every nominal horse power of the engine, one cubic foot of water must be converted into steam per hour, that for each cubic foot of water so required, there should be nine square feet of fire and flue surface, that about 10lbs. of coal is nearly the average quantity required per horse power, per hour.

That the boiler should contain 24 times as

much water as is converted into steam per hour; and as much space for steam as is occupied by the water.

I have endeavoured to give such a description of the ordinary steam engine, found in vessels intended for sea navigation, as should enable any one to understand the general principles on which an engine is constructed, and even to see at once the deviations from ordinary construction, and put him in the way of ascertaining the cause and probability of such deviation.

I would wish that every officer in Her Majesty's Service should feel the same technical familiarity with the different parts of an engine, that they have long had with the details of rigging, &c. and I would remind them, that to attain this knowledge, it is no more necessary to be a blacksmith, than it is for a good rigger to be a rope maker. It is needless to point out how extended steam navigation is daily becoming; vessels of all sizes are crossing the Atlantic monthly and weekly, impelled by steam; of the capacities of this weapon for naval warfare, we can conjecture much, but hitherto we have had but little experience of

them; whatever those powers may be, that nation will be most ready to avail itself of them that possesses the greatest number of persons acquainted with the subject. Our own country is fortunately taking the lead in sea navigation by steam, the proverbial energy and enterprize of British capitalists have set afloat the most powerful sea steamers in the world, and they are daily adding to their numbers and to their power.

Iron vessels of 1500 tons, engines of five or six hundred horse power, are constructing to go to India and to America. All classes are getting acquainted with steam; both by sea and land it is constantly before us, and we must not fall behind any class of our countrymen in a knowledge of that subject by which, in future, our destinies may be guided, our battles may be fought, and it is confidently expected by our country, that our triumphs will be won. We must not disappoint these expectations, and I would once again urge upon any officer who thinks perhaps that a knowledge of machinery and of the principles of steam is unnecessary, this reflection, or rather I would ask him, " are you not persuaded that

a thorough knowledge of seamanship in all its details, is essential, vitally essential to a naval officer? are you not persuaded, that during the last war, many a contest has turned in our favour, not because those who were opposed to us were less brave, or less numerous, or worse armed than ourselves, but because a thorough knowledge of seamanship in all its details enabled our officers to find and make resources, of which our opponents were ignorant? so be you sure, that a knowledge of the details of this new weapon, will give you the same advantages, whether in contests with an enemy, or with the elements.

We all know what a valuable class of men the boatswains of the fleet have always proved, yet with the smartest and best boatswain that ever came afloat, an officer would not feel easy to know nothing about the rigging, and trust all to him.

So with the very best of engineers, no person in command ought to be, or I should think could be, conscientiously satisfied, in ignorance of the names and nature of the power which is to move him.

I hope to be excused for saying a few words

to my brother officers on the subject of engineers:—they are a most valuable body of men, it is our duty and our interest in every way to befriend them; they possess knowledge which we do not, their lives have been spent in acquiring it; much in every way depends upon them; the more we can make these men feel *as belonging to us,* the more we can uphold their situation, the more we can make them feel that they *are officers*, the more we shew them kindness and consideration, the more readily will they enter into our views, impart their knowledge, and in the hour of need, the *greater* and the *safer* will be our mutual reliance on each other.

The engineers whom I have personally known in merchant steamers, were men of a most excellent description, well educated, sober, steady, and with a perfect practical knowledge of their business. If such men as these enter Her Majesty's Service, they will require *consideration;* I will answer for it, they will repay that and kindness a thousand fold. I am not able to speak of the engineers in Her Majesty's ships, as I have had no opportunity of knowing them; but as they form a very

small portion of the whole number in the kingdom, there is no doubt in the event of war, we must recruit our ranks from those employed in the merchant service, and I feel no doubt, that if treated well, they will serve us well.

Having said this much on kindness and consideration for this useful class of officers, I may add, that with them as with the rest of us, our bond of union must ever be strict discipline.

In conclusion, I have only to observe, that as far as sea navigation goes, there is as yet but little difference between the engine I have described, and those in use; the difference is so trifling, and so easy to be understood, as scarce to deserve mention. Hall's condensers are an important change from the injection engine; they have been alluded to farther back.

The opening and closing steam and eduction passages, is open to a great variety of plans. Seaward's slides are highly spoken of, requiring no packing, being kept tight by the pressure of steam on their surfaces; also it is very common to see eduction take place both from above and below, instead of from

below only, as in the engine I have described; the slide in this case is generally in two parts, the depth of each slide being about equal to its travel, and the two connected together by one or two rods, a great deal of weight is saved by this.

Formerly all cylinders were enclosed in a cast-iron casing or jacket, into which the steam pipe opened; but it is now decided that there is more waste of heat from this cause than from a naked cylinder.

In the working parts of engines there is scarcely any difference.

Attempts have been made to do away with the sway beam, &c., and to connect the head of the piston rod directly with the cranks; this is, I believe, now adopted in the Gorgon, one of her Majesty's steamers, but it is not approved of, as yet, by the principal engine makers.

It is, however, in river navigation, that the steam engine assumes every variety of shape, and he who is interested in the various adaptations of machinery to particular purposes, will have his curiosity amply gratified by visiting different boats on the Thames, the Mersey, and the Clyde.

Being limited as to draught of water, and internal space, the arrangement is often totally different from any thing before described; in such boats, the sway beams are often done away with.

It is very common to see the shaft above the deck (covered in), and the head of the piston rod bearing a frame, which works in guides high above the deck, and gives motion to the crank, by means of a connecting rod; this engine, common on the Clyde, is called a steeple engine, but it is unfitted for the open sea.

High pressure engines, with a vibrating cylinder, are in use on the Seine.

The adaptation of the cylinder to the angular motion caused by the connexion of the head of the piston with the crank, is very ingenious.

Another variety of marine engine is Mr. Howard's vapour engine; it has not yet answered the expectations of the ingenious inventor, the principle is the use of distilled water; condensation by cooling the surfaces of the pipes containing the vapour, and generating steam in a particular manner.

While a still greater variety from the common engine is one called a rotatory engine, where

all machinery nearly is done away with, and a direct rotatory motion given at once to the shafts.

All these adaptations of machinery are highly useful and interesting to the student of steam power. I cannot too strongly recommend attention to these matters, to those who have leisure and means.

I have given drawings of each part of the engine in detail, in plates 1 and 2: in plate 3 will be found the external part of an engine, such as I have endeavoured to describe; and in plate 4, a section of a whole engine is given, which though it differs in a few particulars from the description given, will, on that very account, it is hoped, be more useful, as the reader will be prepared for the many variations he will see in practice.

And now that my task is concluded, let me assure my reader, that the great object I had in undertaking it, was to induce all who might honour this book with a perusal to make further enquiries, to set seriously about acquiring a thorough and therefore satisfactory knowledge on this important subject. To lead others to acquire and learn, and to assist them

in doing so, by giving them the alphabet of the science, have been the motives which have induced me to print these remarks.

I am fully aware of the deficiencies and imperfections of this little book, but if it has the effect of inducing any officer, of whatever rank, to give his attention to the subject, I shall not regret having laid myself open to criticism, whatever shape it may assume.

Plate 3, figure 4.

This figure is an external view or elevation of an engine, after the plan of Mr. R. Napier, of Glasgow; most of the ornamental mouldings are left out, and only the lines absolutely necessary are retained.

A, is the cylinder.

a, the steam casing opening into the valve casing *B*.

b, the stuffing box and its cover.

c, the side rod.

d, the cross head of the piston.

e, the radius bar.

f, the plomer block, in which the radius shaft revolves; the dotted line *e′ i*, shews the

motion rod by which the short lever *e'f*, is made to revolve.

g, is the strap, &c., uniting the side rod to the pivot in the sway beam.

B, is the valve casing.

D, the condenser.

E, is the hot well, terminating in the air cone *F*.

G G, is the air pump.

H, is the feed pump, worked by the rod, shewn by the dotted line *H i*.

K, is the sway beam.

i i, are the pivots that work the bilge pump.

m, is the air pump side rod.

l, the cross head of the air pump, working on the guide *n*.

L, is the connecting rod.

o, the cross-tail, or fork-head.

p, the butt end, strap, &c., connecting the cross-tail with the point in the end of the sway beam.

M, is the crank.

N, the intermediate shaft.

O, the eccentric pulley.

P, the counterbalance to the eccentric pulley.

R, the main plomer block.

S, part of the framing, called the diagonal stay.

T, crank frame of the engine.

V, eccentric rod.

W, the gab lever.

X, the valve lifter.

Y, clutch and links, uniting the valve lifter and the rod of the slide valve.

Z, part of the frame which bears against the paddle beam.

h, collar for the packing of the valve.

k k, handle and spring for throwing the eccentric rod in or out of gear.

l, starting shaft and lever, the dotted line *D r*, is the starting bar, and the dotted line *t W*, shews the direction of the back balance link; the back balance lever is in the direction *X W*, prolonged on the other side of the hot well; the end of the lever, works in a socket secured to the counterbalance.

w, is the spindle by which the blow-through valve is worked.

x x x, are the bolts which secure the sole plate to the sleepers; the smaller bolts secure the different parts of the engine to the sole plates.

z z, are the handles for water and steam; the upper one regulates the injection cock, and the lower turns the throttle valve.

Plate 4

Is the section of an engine, showing the principal parts of the engine in their places.

A, is the cylinder, the bottom of which is not cast in one piece with the cylinder, but separate from it.

The cover of the cylinder, its stuffing box and cover are nearly the same as those in plate 1.

The piston is one of the same kind.

B, is the long slide or *D* slide, the faces of the valve are smaller in proportion than those in plate 1, and there is much less cover in consequence.

The packing of the valve is also somewhat different.

A small cover, bolting on at *B a*, which can be taken off when it is desired, to examine the

packing; the valve casing is provided with a cover, stuffing box, &c. similar to the cylinder cover.

C, is the condenser.

b, the main centre.

D, the hot-well.

E, the air pump; the air bucket with the delivery valve down upon it, is not different from that in plate 1.

F, is the foot valve, similar to that in plate 1, the frame in which it stands can be taken out, or the cover taken off when it is required to examine the valve.

G G, is the crank frame.

H H, the diagonal stay.

I, the air cone.

k, the waste water pipe.

L, the air tube.

O, the delivery valve, on the same construction as the foot valve in the condenser.

On the top of the frame in which it stands a cover is secured, which can be taken off when it is desired to examine the valve.

P, is a frame for the valve of the feed pump.

R R, is the sole plate, or foundation plate; in this engine the whole condenser is not cast

in one with the sole plate, but only its lower part.

M, is a short pipe, to the flange of which is bolted the case containing the tail or blow-through valve.

THE END.

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LATE

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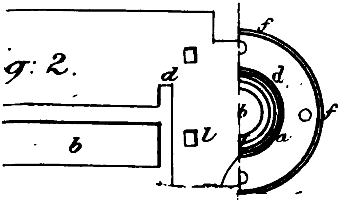
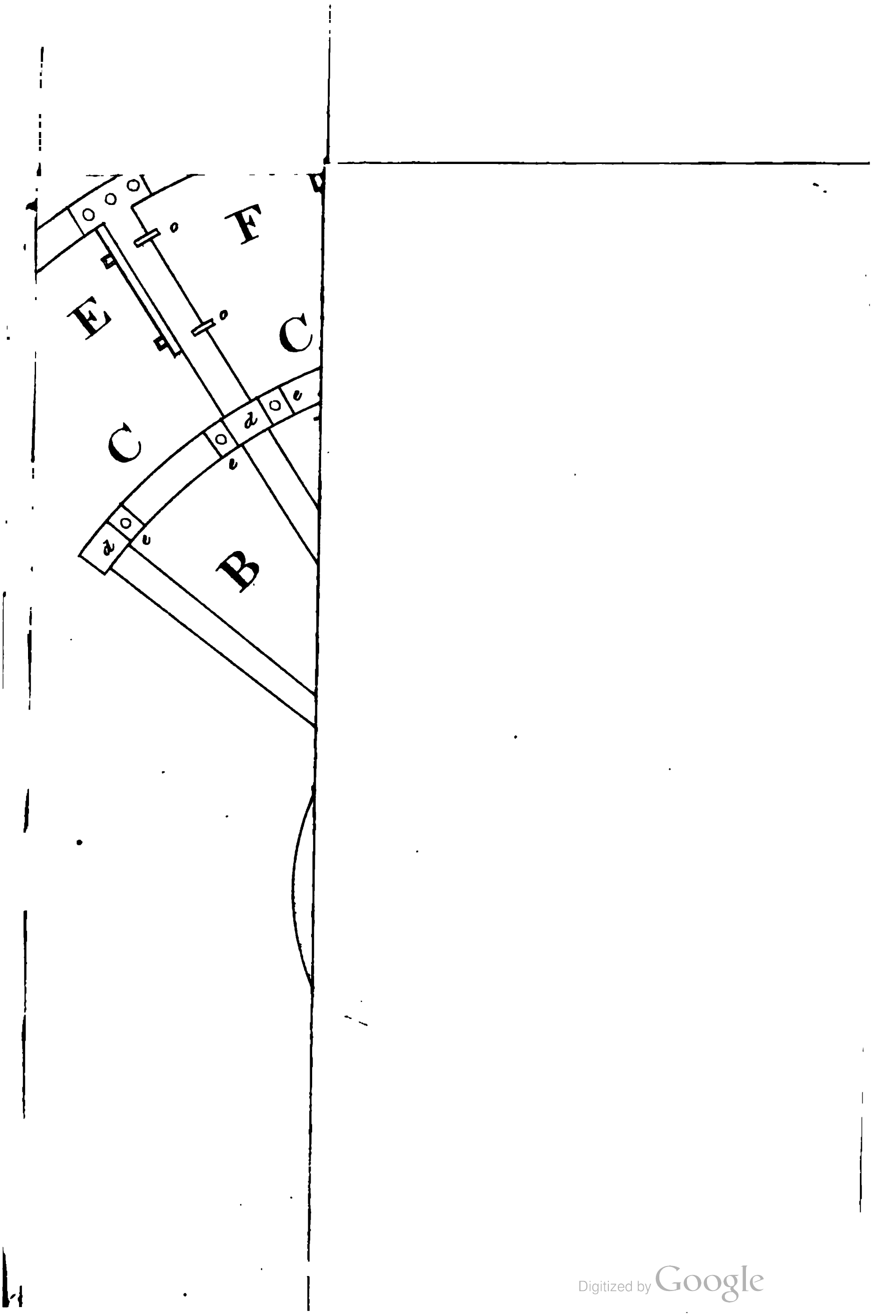


Fig: 5.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